Final Report for

February 25, 2021

Naramata Dam
2020 Dam Safety Review Report

For Regional District of Okanagan-Similkameen

HATCH

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Report

Naramata Dam - 2020 Dam Safety Review Report

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Disclaimer

The Naramata 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.

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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 Naramata 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; and

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Executive Summary

A Dam Safety Review (DSR) of the Naramata 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. Naramata 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 4.4 m^3/s which can be discharged at a reservoir level of 1272.65 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 Naramata 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
NL-1	Dam is currently classified as a Very High consequence facility (FLNROR, 2011).	2020 DSR	-	New	Maintain the Naramata Lake Dam as a Very High consequence facility. Recommend adopting a dual classification system, where the classification for spill capacity alone can be reduced to a High. The Inflow Design Flood would equate to a flood with annual exceedance probability 1/3 between the 1000-year flood and the PMF.	Low
NL-2	Documented history of toe seepage at downstream toe of the dam (EBA, 2010), observed again during the 2020 inspection. A sand boil was noted at the downstream toe.	2010 DSR, 2020 DSR	NCi	Outstanding	Existing construction records and seepage observations, including recent observation of a sand boil, indicate that previous mitigation methods are potentially only partially effective. Design and construct a toe filter blanket and confining berm. Excavate toe material and extend the toe into the ground to intercept under-flows and release foundation pore water pressure.	High
NL-3	Insufficient as-built documents and geotechnical data to conduct a complete geotechnical assessment of the dam. The 2010 DSR recommended a search for historical information and commissioning of a topographic survey (EBA, 2010).	2010 DSR, 2020 DSR	NCi	Resolved/ Outstanding	A topographic survey was completed in 2012. There is limited site-specific geotechnical information. Conduct a geotechnical investigation program and testing similar to the work carried out at the Big Meadow Dam.	High
NL-4	Lack of information on the dam strength against seismic and post-seismic behavior.	2020 DSR	NCi, Pu	New	Conduct a geotechnical assessment of the Naramata Dam for seismic and post-seismic resistance.	High
NL-5	Debris such as silt, sand and gravel, and vegetation accumulated in the spillway channel (EBA 2010). Dam access is provided via a gravel road that crosses the spillway intake. Debris (a log) was observed on this road, crossing the spillway intake. Vegetation/brush was growing in the spillway inlet channel. (Hatch, 2020).	2010 DSR, 2020 DSR	NCm	Outstanding	Short term: Ensure the spillway approach is regularly inspected and clear the spillway approach of debris and vegetation if any blockages are found so that a loss of freeboard does not occur. Any materials should be removed to maintain the spillway intake levels to that of the spillway weir sill. The road should be maintained at a level below the weir crest elevation, with additional armor considered to prevent erosion to the road.	High
			NCm	New	In the longer term, consideration should be given to replacing the road with a small bridge such as bailey style or acrow style steel bridge and extending the excavated channel underneath.	Medium
NL-6	Analysis indicates that the existing dam is able to pass the IDF with an available freeboard of 1.22 m., which is greater than the minimum requirement of 1.0 m (EBA, 2010). Using updated survey data, the 2020 DSR analysis indicates that the existing dam is able to pass the IDF including wind and wave effects with an available freeboard of 0.28 m to the lowest portion of the dam, which meets CDA requirements.	2010 DSR, 2020 DSR	NCm	Outstanding	Restore dam crest to design/typical crest elevation.	Medium
NL-7	Piping risk assessment shows that the risk of piping failure is higher than the tolerable limits defined by the CDA Dam Safety Guidelines. This was also noted in the 2010 DSR (EBA, 2010)	2010 DSR 2020 DSR	An	Outstanding	Assessment shows that piping risk is greater than the tolerable threshold, particularly for piping risk through the foundation. This is supported by observations of boils downstream. The risk of piping through the foundation should be addressed by the construction Internal piping potential and stability should be analyzed part of future geotechnical investigation and assessment of a toe berm as noted above.	High
NL-9	No Operations, Maintenance and Surveillance (OMS) manual was prepared for the dam as of the previous Dam Safety Review	2010 DSR	N/A	Resolved	An OMS manual has been published since the previous review (RDOS, 2017). The contents of the OMS were reviewed and revised as part of the 2020 review.	Medium
NL-10	Dam Safety Review schedule	2020 DSR	-	New	In accordance with the Very High consequence classification, the next Dam Safety Review should be conducted in 2030, and every 10 years subsequently.	Medium
NL-11	No information is available for the rate of drawdown and the procedures that should be used to accommodate lowering the reservoir for emergency drawdown.	2020 DSR	NCo	New	It is recommended to determine a better understanding of the rate of drawdown that can be achieved for emergency drawdown scenarios such as with the sand boil. A plan to utilize a portable syphon or one or more high volume pumps to provide capacity and emergency drawdown would be a cost effective way to providing required drawdown capacity. This should be evaluated for operations planning as well as potential sources for emergency pumps if needed. Under the CDA guidelines, it is recommended to provide information on staffing requirements and the time required to complete system operations. Add syphon Standard Operating Procedure (SOP) to OMS Manual.	Medium
NL-12	Lack of sufficient instrumentation for performance monitoring.	2020 DSR	NCi,s	New	Install new instrumentation including piezometers and reinstate/install weirs downstream of the dam along the channels. Piezometer installation will be carried out as part of geotechnical investigation.	High

Issue No.	Deficiency/Non-Conformance	Originator	Type	Status	Recommendation	Priority Rating
					The instrumentation monitoring shall include continuous records, plotting, and interpretation of piezometer data and seepage flow quantities against reservoir elevation.	
NL-13	Lack of sufficient instrumentation for performance monitoring.	2020 DSR	NCi,s	New	It is recommended that an automatic water level gauge be installed on Naramata Lake, calibrated and regularly maintained to better monitor changing water levels.	Medium
NL-14	OMS could be improved by providing additional information on procedures regarding instrumentation. This will assist Dam Safety inspectors in detecting and responding to an emergency situation.	2020 DSR	NCs	New	Procedures regarding instrumentation (piezometer) readings and data processing should be added to the OMS. This includes where 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. Plot piezometer locations plan and report flows. Pipe flows should be measured by bucket filling and documented.	Medium
NL-15	Vegetation control along the tailrace channels	2020 DSR	NCs	New	Increase frequency of vegetation clearing along the tailrace trenches for future seepage/piping monitoring.	High
NL-16	Currently no rip-rap 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.	
NL-17	LLO structure is unprotected from vandalism and accidental damage from ATVs or other traffic at dam crest.	2020 DSR	NCm	New	Provide protection to the screw stem by adding bollards or a steel cover to prevent damage from ATV traffic.	Low
NL-18	Recommendations recently provided to increase public safety and reduce risk to RDOS.	2019 Risk Survey, 2020 DSR	NCp	Outstanding	Review security protocols and implement appropriate restrictions including those set out in the 2019 Risk Control Survey (Precise Services, 2019) to prevent damage or vandalism.	High
NL-19	Minor concrete cracking in localized area around outlet pipe in LLO structure	2020 DSR	NCm	New	Repair the cracked area of concrete after chipping off the loose and cracked concrete section	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 aspect 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 Naramata Lake 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 Naramata 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 Naramata Dam components have been summarized at the end of this report. The recommendations have been ranked using the prioritization system outlined in Section 13.

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.

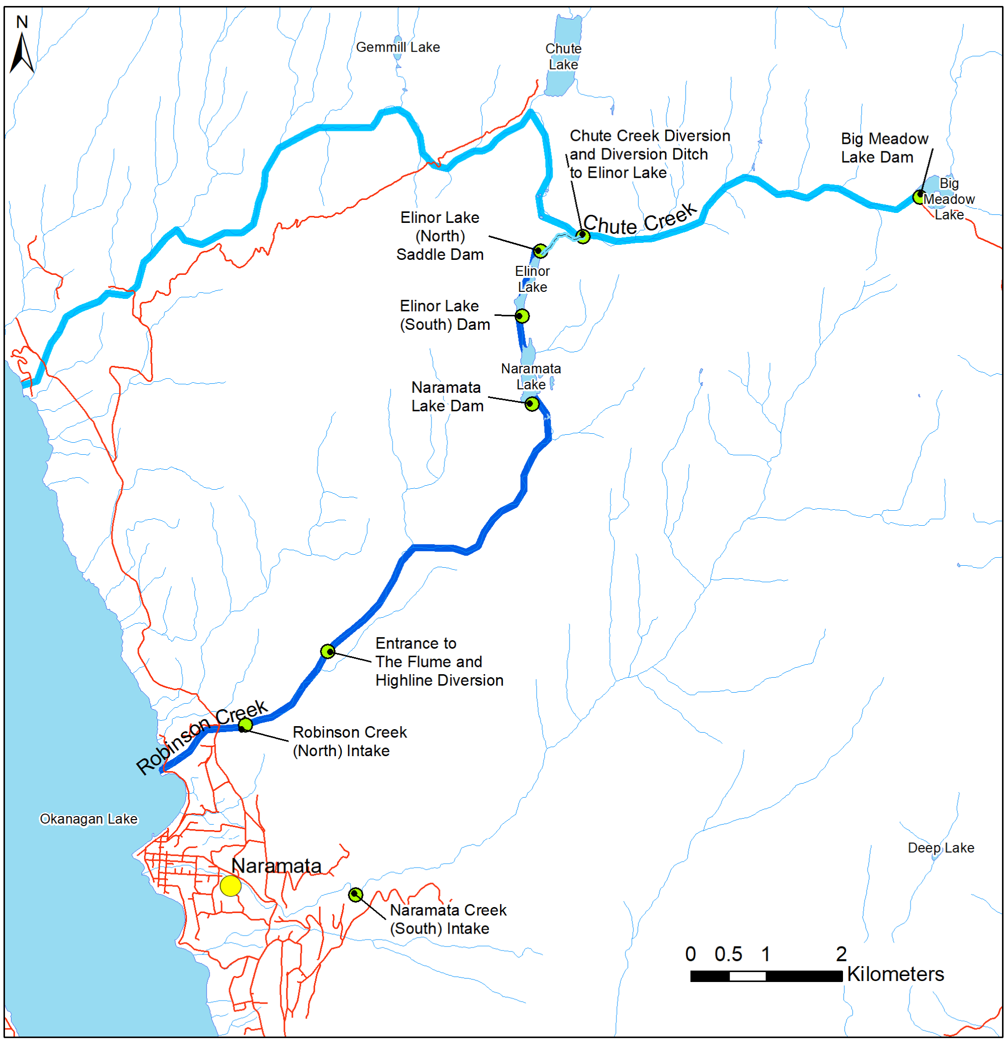


Figure 2-1: Naramata Dams Location Map

The Naramata Lake Dam is 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 potable water due to the construction of the Naramata UV Water treatment Facility in 2006. 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 Naramata Dam is situated in a north to south trending valley approximately 7.5 km to the northeast of Naramata Township. Flows from the upstream Elinor Lake discharge into the Naramata Lake. Naramata Lake is formed by an earthfill dam, which is approximately 116 m long and 9.1 m high at its maximum height and has a crest elevation that varies between 1273.09 m to 1273.97 m. Vehicle access to the Naramata Lake Dam is provided via Elinor Lake Forestry Service Road, which extends off of Chute Lake Road to the north which in turn extends off of 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: Naramata Lake Dam Major Component Layout

The key physical dimensions of Naramata Dam are in Table 2-1:

Table 2-1: Key Dimensions of Naramata Dam

Structure	Details
Type of Dam	Embankment Dam (Zoned Earthfill)
Maximum Height	9.1 m
Crest Length	116 m
Crest Width	3.7 m
Crest Elevation	1273.09 m minimum to 1273.97 m maximum;
Upstream Slope	4H:1V
Downstream Slope	3H:1V
Approx. the left third of the embankment slopes downstream	6H:1V
Retained Water (at spillway crest)*	795,000 m^3
Low Level Outlet	Concrete with metal gate, 1262.5m invert elevation 0.76 m diameter Estimated capacity of 0.42 m^3/s
Spillway	Concrete overflow, 4.6 m wide Spillway crest elevation 1271.95 m Estimated capacity of 1.33 m^3/s at 0.33m
Dam Failure Consequence Classification	Very High

*729,000 m^3 is the volume associated with spillway crest of 1271.5 m. A topographic survey was recently conducted finding that the spillway crest elevation is 1271.95 m. What is shown is the corresponding volume from the stage-storage curve.

2.3 History of Dam and Reservoir

The Naramata Dam is situated at the confluence of two valleys with the dam originally comprising two embankments (east and west) situated at the outlet from each valley. With the raising of the dams in 1967 the two embankments became one dam.

There is some uncertainty as to when the original Naramata Lake Dam was originally constructed. The existing drawings suggest that it was originally constructed in 1912, raised in 1937 and raised again in 1967; however, the dam information board states that it was originally constructed in 1943 and raised in 1967. A review of the oldest available aerial photography from 1938 indicates that recent embankment construction had occurred suggesting that the 1937 date may be correct. During this study, an online search led to the discovery of a publication in the Canadian Geotechnical Journal. This paper documents the construction of earth dams for water supply and irrigation purposes in the Okanagan at the start of the 20th century. Although there are limited historical records prior to 1920, the author cited Wilson (1989) and documented that “a small dam in the hills behind Naramata gave way, probably in 1914” This statement was based on a 1917 annual report the by Water

Rights Branch that describes work to repair the community reservoir dam that broke three years prior. This could further explain the history of the dam.

The original dams presumably constructed in 1912 appear from the drawings to have been comprised of homogenous low permeability fill with a maximum embankment height of approximately 3.5 m. In 1937, the dams were raised to a maximum height of approximately 6.1 m with the placement of more low permeability fill.

In 1967, the dam was substantially rebuilt as a zoned earth dam, comprising a low permeability upstream shell, a granular downstream shell with a downstream foundation filter incorporating pipe drains with a maximum height of 10.7 m. The existing drawings indicate that it has a 4H:1V slope upstream and 3H:1V slope downstream. At the time, the existing low-level outlet was excavated, removed and replaced.

In June 1969, a seepage problem, in the form of a boil, developed at the left abutment toe of the dam. The seepage was controlled by removing overburden; installing a select filter blanket to prevent sloughing or minor failures from occurring that could affect the overall stability of the dam; and placing an overlying zone of select pervious material weighing the area of the boil. Inspection reports indicate that several standpipe piezometers were installed in this area during the late 1960's and 1970's to monitor pore pressures in this area of the embankment. It is assumed that this instrumentation has either been destroyed or no longer functions and has been abandoned as there were no signs of it found during the dam inspection.

Due to the ongoing seepage issues at the toe of the left downstream slope of the embankment, the slope of the dam was flattened in this area with placement of additional granular fill to a gradient of approximately 6H:1V in 1988. Included in the 1988 upgrade works was the installation of a new standpipe piezometer in this area. It is believed that this is the piezometer that is still currently functioning in the 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 at the Naramata Lake 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 Naramata Lake 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 [CDA, 2013a], and the B.C. Water Sustainability Act and the B.C. Dam Safety Regulation (Reg. 44/2016). Prior dam safety reports and other reports pertaining to the safety of Naramata Lake 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 upon the potential of the issue leading to 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 Naramata Lake Dam.

The findings of the DSR were documented in this DSR 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
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

File Name	Data	Description
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
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

File Name	Data	Description
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
Big Meadow Dam – Naramata, BC, Golder Memo	2 November 2004	Golder Co. Correspondence Re repairs of the dam toe

4.2 Data Gaps

RDOS provided information available for Naramata Dam including some of the engineering and dam safety studies that have been completed for the Naramata Dam during the life of the structure. This documentation included previous dam analyses conducted by external consultants 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 around 1937 and raised in 1967 and have largely gone unchanged throughout the intervening years. A complete record of information on the design and construction of the dam was not available. 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 construction specifications
- A lack of geotechnical information including:
  - Material gradation
  - Density of the foundation material information
  - Shear strength tests on the impervious fill and foundation clays
  - Piezometric elevations in the foundations.

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 Naramata Lake 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 Naramata Lake Dam site and RDOS's operations and maintenance staff.

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

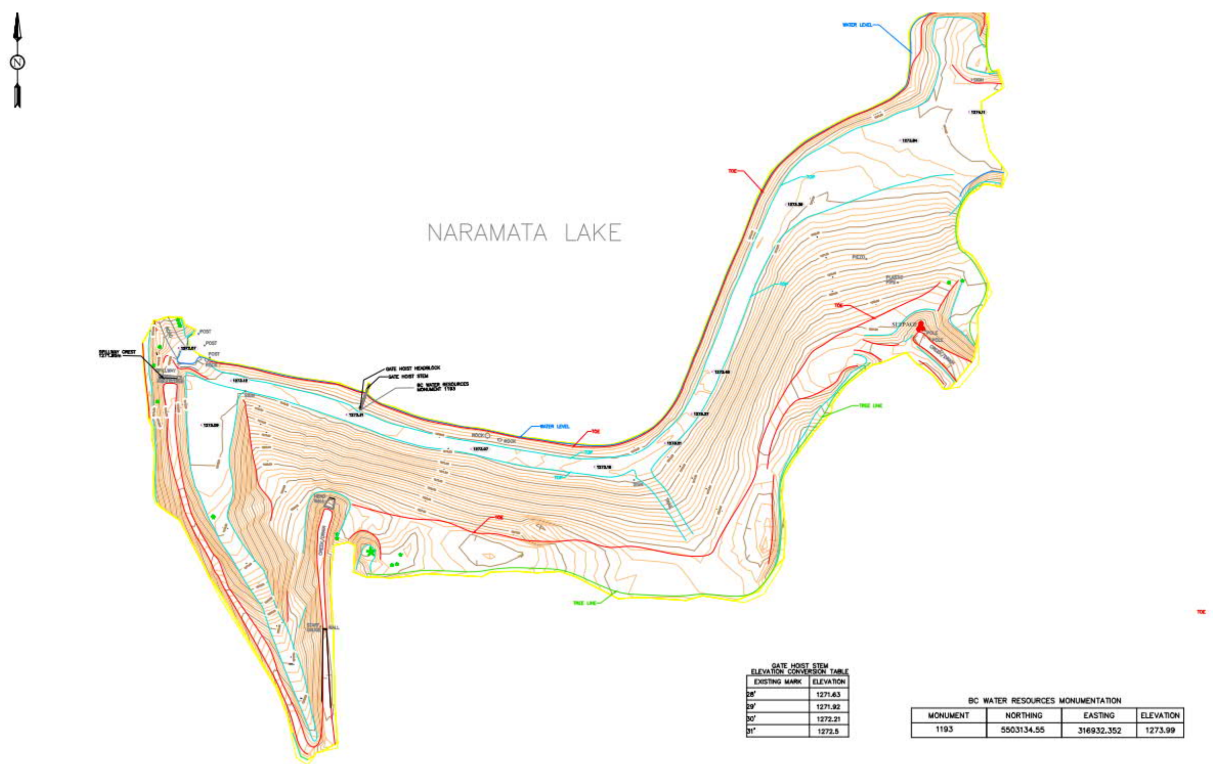


Figure 5-1:Naramata Lake Dam Site Plan and Topography

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 surrounded by natural higher ground with a dense tree cover surrounding. A review of the reservoir rim at the dam crest was completed and was found to be well maintained in this area. RDOS did not raise any issues regarding the reservoir rim. No significant dead wood was observed in the lake which would supply debris that could potentially impact the structure or spillway. Grass and low-lying vegetation was observed on the upstream and downstream dam slopes (see Photos A1 and B1 in Appendix A) which suggests that the vegetation control program was satisfactorily implemented with the exception of vegetation and shrubs growth along the spillway channel and side slopes. Vegetation along the spillway channel was also reported during the 2010 DSR (EBA, 2010).

No riprap or erosion protection system was observed on the upstream dam face; however, granular materials were noted on the upstream face based on a review of photos taken during low water levels. As recommended in the previous DSR (EBA, 2010), the frequency of vegetation clearing should be increased along the spillway and slopes to facilitate inspection and prevent reduction in capacity (see Issue No. NL-5 in Table 13-1).

5.1.1 Freeboard

The dam crest elevation varies along its entire length and ranges between 1273.09 m and 1273.97 m.

Flood routing and freeboard analyses were completed based off the existing dam crest elevations. The results indicate that the existing freeboard will provide adequate protection against wind generated waves. Given that there is currently no rip-rap or erosion protection layer on the dam crest or upstream slope, it is recommended that RDOS inspect the dam after large wind storms to confirm if any deterioration 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 is recommended. (see Issue No. NL-16 in Table 13-1).

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

5.2 Naramata Earthfill Dam

The Naramata Lake earthfill dam is a zoned embankment consisting of an upstream impervious shell and a downstream granular shell. A filter blanket and drainage pipe embedded in granular materials were constructed on the downstream side of the dam for seepage collection. There are two existing drainage outlet pipes on the left and right sides of the dam which collect the seepage on the downstream slope of the dam and discharge to two channels on the downstream toe.

The upstream face of the dam has a shallow slope (4H:1V) with no riprap or other means of erosion protection system. Note that the reservoir level was high at the time of inspection which hindered an inspection of the upstream slope. A review of the previous site inspection indicates that the upstream face of the dam is covered by granular materials for erosion protection. The freeboard of the dam was also covered by vegetation at the time of inspection. Considering the small fetch of the dam and good performance of the upstream face, the absence of riprap is only a minor concern. Minor vegetation growth was observed on the upstream slope and RDOS should continue to implement the existing vegetation control plan so that erosion related observations can be easily made during typical surveillance tasks.

The downstream slope of the Naramata Dam was found to be comprised of rounded pit-run granular materials covered by light grass (see Photos A4 to A7 in Appendix A). The downstream slopes were of variable pitch between different sections. Close to the left abutment, the downstream slope appeared to be significantly flattened during previous repairs. Vegetation growth does not appear to be a major problem at the downstream slope of the dam. However, it is recommended that vegetation control be extended beyond the dam toe, typically 3 m, to facilitate the inspection of the downstream toe. Since this dam has had problems in this area previously this is particularly important to prove early identification of potential problems and prevent them from ever becoming a dam safety issue. No erosion of this slope was noted.

The crest of the Naramata Dam is a publicly accessible road paved with granular materials and was in good condition. The design dam crest level is at El. 1273.15 m. The 2010 survey indicated the crest elevation at its lowest level, at El. 1273.07 m, close to the right abutment and at its highest level, El. 1273.97 m, close to the left abutment. Even though the dam crest is technically deficient by 0.08 m freeboard is still adequate for the structure as discussed in Section 5.1.1.

Two channels carry water away downstream from the left and right side of the dam. The main flow from the Low-Level Outlet (LLO), spillway and several drainage pipes discharge into the right channel. Only drainage pipes discharge to the left channel. One V-notch (rectangular shape) weir is installed downstream of the right trench (downstream of the LLO), which does not appear to be functional (see Issue No.NL-12 in Table 13-1). As is discussed later we recommend refurbishing and monitoring this weir as well as installing another weir in the right channel to properly monitor seepage through the dam. Other flow monitoring methods could also be considered as opposed to V-notch weirs.

One piezometer exists on the downstream slope of the dam, close to the left abutment, and the water level was read during the inspection (See Photo A14 in Appendix A) however no details of the piezometer installation were found. It was observed that the piezometer was recording water levels at a very critical location and the water level fluctuations correspond well to the upstream reservoir fluctuations.

No issues were noticed on the slopes, crest, and left and right abutment of the dam related to vegetation control.

Since a topographical survey of the dam was carried out in 2010, a new survey is not necessary at this time. It is recommended that a new survey be completed prior to the next DSR which is expected to happen in 10 years. (See Issue NL-3 in Table 13-1).

5.3 Spillway

The spillway structure and channel were observed by Hatch during the site inspection (see Photos A9 to A12) and appeared to be in good condition. The spillway consists of a 4.6 m wide concrete overflow weir. Although there are guides in place for stoplogs these have been decommissioned and are no longer used.

There is a debris boom upstream at the inlet structure to prevent debris from clogging the weir. This boom should be adequate for this purpose provided debris is removed on a regular basis and not allowed to build up excessively. Dam access is provided via a gravel road that crosses the spillway intake, which includes a depression in the dam crest close to the right abutment of the dam. The spillway weir discharges to a trapezoidal channel excavated in the overburden close to the right abutment, and the spillway channel terminates at the invert of the outlet channel at Robinson Creek, approximately 150 m downstream.

Erosion protection in the downstream spillway channel includes vegetation as well as some remnants of riprap that were observed. Riprap coverage appeared to be sparse. The spillway discharge channel was found in good condition with no sign of erosion or distress.

At the time of inspection, there was a small amount of water flowing over the spillway weir.

The concrete in the visible sections of the spillway elements was generally found to be in good condition with no visible damage or signs of deterioration, spalling or any exposed rebar. The side walls, and the centre pier of the channel were visually verified, and no signs of tilting or deformation were noted. The surface of the top of the spillway weir was covered in a layer of silt and the side walls had vegetation growth (see Photo 10), due to which only parts of the spillway elements were visible. Riprap lining was present downstream of the spillway crest and there were no signs of undermining of spillway crest structure. It is recommended that the vegetation growth in the spillway walls and on the crest be cleaned to maintain the flow through the spillway and to prevent deterioration of concrete of spillway crest.

The roadway above the spillway section was in reasonable condition with no signs of settlement or localized subsidence or depressions in the roadway fill. However, the section of the roadway at the spillway location did not have any riprap lining (see Photo 9). The flow of the water above this section of the road was fairly slow at the time of the site visit and no erosion was observed during the site visit. During the event of high flows through this section, the erosion of the roadway could be possible and has resulted in damage to the roadway. The presence of this road upstream of the weir is a potential problem because of the potential for it to restrict flow to the spillway and the competing desire to prevent damage due to flows. For this reason, we recommend the road be maintained at a level below the weir crest elevation in the short term with additional armor considered to prevent erosion. In the longer term a more satisfactory solution would be to extend the spillway approach channel through the road and span it with a short bridge.

The spillway channel was fairly clean with no large debris accumulations, however a log was observed within the spillway inlet channel downstream of the boom, as well as vegetation/brush growing at the entrance near the reservoir rim. This log was likely from the local area and should be removed as part of the ongoing maintenance of the structure.

There is a debris boom upstream at the inlet structure to prevent debris from clogging the weir. This boom should be adequate for this purpose provided debris is removed on a regular basis and not allowed to build up excessively.

5.4 Low Level Outlet Intake Structure

The intake system comprises of a 24-inch diameter concrete pipe, which runs along the base of the embankment dam and is installed on the reinforced concrete bedding. A slide gate is installed at the upstream/intake end of the pipe culvert. The slide gate is connected with a steel gate stem and is operated via a rotating wheel assembly at the dam deck level. Most part of the intake structure was under water during the site visit and therefore could not be visually inspected. Only the section of the wheel assembly and its concrete anchor support at the dam crest, and some portion of the intake gate operating rod were visible above water (see Photo A13). The concrete at the wheel block support assembly appeared to be in good condition. Some signs of corrosion were observed on the gate operating stem and the wheel assembly. A section of the gate operating stem near the operating wheel assembly appeared to be slightly bent downwards (see Photo A18) and there was no visible clearance between the rod and the concrete base. It is possible that the gate stem was bent due to accidental impact or falling of heavy object but the exact reason is unknown. According to site staff, the intake gates operate successfully, and no concerns were indicated related to the operation of these gates. The operation of the intake gate was not verified during the site visit. Even though the gate is currently operating successfully, the repair of the bend in the section of the gate stem is recommended to ensure a successful long term performance of gate operation.

The inspection of the trash rack grill at the inlet and the concrete support structure at the inlet of the culvert is recommended to be performed during the time of low lake levels, for any signs of distress, settlement or damage. The observations from the inspections should be documented for future reference, and any concerns if found, should be addressed.

A significant ATV traffic activity appears to be present in general at the dam site with ATV tracks on downstream slope of dam (see Photo A4). The dam area is open for recreational use and there is no fence around the dam crest. Since the operating wheel assembly is located at the dam crest, a possible concern could be potential damage to this operating structure due to accidental ATV activities or vandalism. In the event the structure is vandalized, the damage may remain unnoticed for several days as the dam site is not manned. It may be concerning if the gate operating assembly is found to be damaged/ inoperable in an event a gate operation is needed in emergency during an extreme flood or after a major seismic event. Concrete barrier blocks or fencing of the area should be considered around the wheel assembly and the gate rod as a precautionary measure. These types of solutions can prevent the potential risk of damage to the operating structure and can be implemented at a relatively low cost.

5.5 Low Level Outlet – Outlet Structure

The outlet is a concrete retaining wall structure at the downstream toe of the dam, as shown in the existing drawing No. 226-02-4. This structure supports the downstream end of the 24-inch diameter culvert pipe.

The concrete of the outlet structure was found to be in good condition. There was no evidence of any major damage, spalling of concrete or exposure of rebar (see Photos A7 and A19). The walls of the outlet structure were visually verified, and no signs of tilting or deformation were noted. A minor crack was observed in the retaining wall which supports the downstream toe of the dam, at the location of the outlet pipe section (see Photo A19). This crack does not appear to be a concern however it should be repaired to prevent further damage to the outlet structure and to prevent any erosion of downstream toe material in case this cracked section separates and falls out.

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 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.
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 Naramata Dam is currently classified as Very High. The report, "Hydrotechnical Assessment of the Naramata Dams" (2010) was produced in tandem with the previous Dam Safety Reviews by EBA Engineering Consultants, which classified Naramata Dam as High. In 2011 a review by the Ministry of Forests, Lands and Natural Resource Operations, Resource (FLNROR) Stewardship Division, increased the consequence classification for Naramata Dam from High to Very High. The consequence classification was based on the downstream risks associated with a dam failure, based on BC Dam Safety Regulation Schedule 1, Determination of Classification as follows:

- Population at risk: Permanent
- Consequence of failure:
  - Loss of life: 100 or fewer
  - Environment and cultural values: Significant loss or deterioration of:
    - critical fisheries habitat or critical wildlife habitat,
    - Rare or endangered species, or
    - Unique landscapes or site of cultural significance, and restoration or compensation in kind is possible but impractical.
  - Infrastructure and economics: Very high economic losses affecting important infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas.

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 (2021).

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.

Naramata 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 lower than for fair weather conditions. Results confirm that the overall classification for Naramata Dam is “Very High”, but 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 only).

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 Naramata 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 summarizing 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 and a spillway, 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 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.

Table 7-1: Hazard and Failure Modes Matrix for Naramata 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**	Improbable – Spillway can safety pass IDF							
Inadequate available discharge capacity	**Inadequate reservoir operation (rules not followed)**	Improbable – Debris blockage could cause over topping. Mitigated by spillway design, debris supply, debris boom, and inspection	Improbable - LLO is the only operable equipment and it is not required for flood control.	Improbable - Reservoir slopes are stable; Little debris in reservoir, and debris boom is in place upstream of spillway.		Improbable - LLO is the only operable equipment and it is not required for flood control. Spillway can pass IDF without overtopping of structure.	Improbable - LLO is the only operable equipment and it is not required for flood control.		Improbable - LLO is the only operable equipment and it is not required for flood control. spillway can pass IDF without overtopping of structure.
	Random functional failure on demand	Improbable – no spillway gates. LLO tested regularly.	Improbable – no spillway gates.	Improbable – no spillway gates.	Improbable – no spillway gates.	Improbable – no spillway gates.	Improbable – no spillway gates.	Improbable - No mechanical or electrical equipment required for flood control.	Improbable – no spillway gates.
	Discharge capability not maintained or retained	Improbable - Debris blockage could cause over topping. Mitigated by low debris supply, debris boom, and inspection. Potential for ice blockage is improbable due to operating timeframe. Possible - Vegetation in spillway channel could reduce spillway capacity, or spillway crest elevation not maintained at access road.		Improbable – Ice jam in front of spillway causing blockage. Grounded ice in lake floats towards spillway. Slope slide from surrounding topography (low probability). Debris blockage could cause over topping. Mitigated by low debris supply, debris boom, and inspection.	Improbable- fixed crest spillway with capacity to pass the IDF. No fence around LLO structure could lead to vandalism of that gate mechanism.	Improbable - Debris blockage could cause over topping. Mitigated by debris supply, debris boom, and inspection.	Possible – Design of spillway has the access road pass upstream of the spillway crest. Spillway capacity could be reduced if the spillway access road is not maintained at the same level or lower than the spillway weir crest. Not an ideal configuration. .		Possible – Design of spillway has the access road pass upstream of the spillway crest. Spillway capacity could be reduced if the spillway access road is not maintained at the same level or lower than the spillway weir crest. Not an ideal configuration.
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 - Elinor South Dam is immediately upstream, which is a hazard if it fails.	Improbable –The potential for the wave created by a landslide has not been specifically studied but likely not credible based on topographic information. Possible - Elinor Dam is immediately upstream, which is a hazard if it fails under a seismic event.	Improbable – Potential for landslide into reservoir is unlikely based on topographic information.		Improbable - Dam could be overtopped and fail if upstream Elinor South Dam were to fail. However, Elinor South Dam can pass the PMF therefore risk of failure is low. No landslide hazard identified.			Possible - Road upstream of spillway could cause a constriction and reduce spill capacity if not maintained lower than weir elevation. Roadway needs to be regularly maintained and inspected to prevent this. Consideration should be given to installing a bailey or acrow style bridge in the future to remove this potential.
	Wind-wave dissipation inadequate	Improbable - meets 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.		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.	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.

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
		Helicopter access should be considered in an emergency							
	Operation, maintenance and surveillance fail to detect poor dam performance	Possible - little instrumentation or seepage monitoring. Mitigated by weekly inspections. Boiling during high water level happened at RDOS dam sties but was detected and responded to appropriately and in a timely fashion.. However, meteorological event could make dam inaccessible and therefore prevent the Dam Safety Engineers activities. Helicopter access should be considered in an emergency	Possible – LLO dependency becomes important if known piping issue occurs, as it has in the past when water levels approach the spillway crest. If distress in dam occurs after a seismic event and the LLO is damaged, there is currently no method or procedure in place to lower the reservoir. Consideration should be given to a portable siphon system to lower the reservoir in case of emergency.	Improbable - Good OMS procedures and little expected influence from reservoir environment.		Possible - insufficient 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
Stability under applied loads	**Mass movement (external stability:- displacement, tilting, seismic resistance)**	Improbable - Dams 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 - access controlled by fence.	Improbable - Dam meets seismic stability requirements.			Improbable - regular inspections.
	Loss of support (foundation or abutment failure)	Improbable - Dams meets stability requirements.	Improbable - Dam meets seismic stability requirements.		Improbable - access controlled by fence.	Improbable - Dam meets seismic stability requirements.			Improbable - regular inspections.
Watertightness	**Seepage around interfaces (abutments, foundation, water stops)**	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 followed by investigation.		Improbable - access controlled by fence.	Possible – 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 followed by investigation.		Improbable - access controlled by fence.	Possible – 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)**	Improbable	Possible - Dam foundation susceptible to Liquefaction. Investigation and Assessment needed.		Improbable - access controlled by fence.	Possible - Dam foundation, upstream core and shell materials might be susceptible. Investigation and Assessment needed.			Improbable - regular inspections.
	Instantaneous change of state (static liquefaction, hydraulic fracture, seismic cracking)	Improbable	Possible - Dam foundation susceptible to Liquefaction. Investigation and Assessment needed.		Improbable - access controlled by fence.	Possible - Dam foundation susceptible to Liquefaction. Investigation and Assessment needed.			Improbable - regular inspections.

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). In lieu of having gauges located directly within the study watershed, the previous flood frequency analysis for this location was conducted using Water Survey of Canada (WSC) gauges 08NM240 (Two Forty Creek near Penticton), 08NM242 (Dennis Creek near 1780 m Contour), 08NM168 (Penticton Creek above Dennis Creek) and 08NM035 (Bellevue Creek near Okanagan Mission) [EBA Engineering Consultants, 2010]. As is industry standard given the data available, a regional flood frequency analysis was completed using these WSC gauges, selected due to their proximity to the reservoirs and downstream catchments, and the length of recorded data available. Gauge 08NM240 (Two Forty Creek near Penticton) is located within the upper reaches of its watershed area and has 34 years of recorded flow between 1983-2017. Gauge 08NM242 (Dennis Creek near 1780 m Contour) is also located within the upper reaches of its watershed area and has 32 years of recorded flow between 1985-2016. Gauge 08NM168 (Penticton Creek above Dennis Creek) has 28 years of recorded flow between 1970-1999. Gauge 08NM035 (Bellevue Creek near Okanagan Mission) is located within the lower reaches of its watershed area and so comprises a larger area of approximately 73 km^2. It has 28 years of recorded flow between 1920-1986. Flow records as listed above have been updated to the current date to demonstrate the number of additional records available since the 2010 analysis. Table 7-2 illustrates the results of this analysis.

One important discrepancy to note between the two analyses is that the 2010 analysis used the entire watershed area upstream of the Chute Creek diversion structure was considered an option in the assessment for Elinor Lake and Naramata Lake, and results using these watershed areas were ultimately reported as the extreme flows at Naramata Lake Dam. This appears to have been included as a scenario to consider before the practice of closing the Chute Creek Diversion gates once the Naramata and Elinor reservoirs reached a certain level was put into place, as it is now.

The watershed area upstream of the Chute Creek Diversion was not included in this assessment because the Diversion gates are closed prior to the Elinor and Naramata Dams reaching their spillway crests and the diversion channel has an extremely limited capacity. This was confirmed based upon information gathered and observed during the site visit, available LiDAR data, and the corresponding dam breach modeling assessment that has been completed along with this study. Additional data collected at the active gauges since the 2010 assessment was included in Hatch’s assessment.

Table 7-2: Flood Frequency Analysis Comparison

Return Period (years)	2010 Flood Frequency Analysis: Peak Flow (m^3/s)	Current Flood Frequency Analysis: Peak Flow (m^3/s)
2	1.6	1.1
5	2.2	1.4
10	2.7	1.6
20	3.1	1.7
50	3.7	1.9
100	4.3	2.1
200	4.8	2.2
1000	5.9	2.5
PMF	41.2	8.3

A PMF analysis was completed for the Naramata 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, using the updated watershed areas that do not include the Chute Creek catchment.

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. Note that during this study, the availability of high-resolution digital elevation data allowed for the delineation of the diversion channel connecting Chute Creek to Elinor Lake through the Chute Creek Diversion. The approximated area expected to contribute to flow into the diversion channel through natural runoff directly into the diversion (downstream of the diversion structure) was added to the Elinor Lake watershed area, which related to a slight increase in drainage area for the reported local watershed area of Elinor Lake.

Table 7-3: PMF Peak Flows

Dam	Watershed Area (km^2)	Peak PMF (m^3/s)
Elinor Lake North Saddle Dam and South Dam (local area)	1.3	2.7
Naramata Lake Dam (local area)	4.4	8.3

As can be observed in Table 7-2 the updated return period flows and PMF are substantially lower than previously assessed. Further discussion of this can be found in Naramata Dam Breach Assessment and Inundation Mapping (2021) however the main reason for this discrepancy is that the 2010 analysis considered the entire drainage area upstream of the Chute Creek diversion in the analysis. Given current operating rules that close the diversion during major floods and the extremely limited capacity of the diversion channel this was an extremely conservative and unrealistic assumption. The current assessment provides a much more realistic assessment of potential design flood events.

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) a summary of the operation of Naramata Dam is provided as follows.

Aside from the operation of the Chute Creek Diversion to assist in the filling of the Naramata Reservoir, the only operable portion of the Naramata Dam is the low-level riparian conduit structure described in Section 3. It has been historically estimated that this outlet was designed for the passage of approximately 0.42 m^3/s, presumably with the reservoir at the FSL elevation of 1271.95 m. This capacity is far less significant during a large flood event, compared to the volume of flow that can be passed by the spillway.

However, the previous Naramata Dam OMS and EPP (2017) suggests that if the run-off water is excessive, the outlet gate can be opened to relieve some of the inflow. In general due to the design of these low flow outlets for more normal reservoir water levels and backwater conditions as well as the relatively small capacity of these types of structures compared to spill capacity during a flood this type of action is NOT recommended. If operated during a major flood there are dangers of excessive erosion downstream of the conduit as well as damage to the conduit and gate due to air demand exceeding available venting at the structure. As the spillway can safely pass flows in excess of the IDF operation of the conduit during a flood should not be required.

7.2.3 Discharge Capacity

There are two (2) structures that provide discharge capacity at Naramata Dam. These are the low level outlet and the uncontrolled concrete overflow spillway. Both structures were reviewed to confirm that the assumptions made in their design are appropriate.

7.2.3.1 Low Level Outlet

The low level outlet is described in Section 3. The main use of the low level outlet is to pass flow from the lake to maintain a minimum downstream riparian flow. The Naramata Dam OMS and EPP (2017) suggests that if the run-off water is excessive, the outlet gate can be opened to relieve some of the inflow. However, as stated above this runs the risk of damaging the structure and should not be used in this fashion. It is not required as the IDF can be accommodated through the spillway. A rating curve was not found for this structure, though its estimated capacity has been reported as 0.42 m^3/s.

7.2.3.2 Spillway

Naramata Dam's spillway is an uncontrolled concrete overflow weir that discharges to an excavated channel. It is located at the west abutment of the dam. The spillway is 4.6 m wide. Both the exit and approach channels are excavated channels.

A design spillway rating curve was not found within the available data collected during the study. The discharge capacity was assessed in the Hydrotechnical Assessment of Naramata Dams [EBA, 2010]. The broad-crested weir equation was used along with the geometry of the spillway, assuming a discharge coefficient of 1.65. The only additional reference to spillway capacity is in the OMS and EPP, and is estimated as 1.33 m^3/s at 0.33 m of head. Hatch reviewed the coefficient used and determined it was reasonably appropriate. In order to obtain a match to the estimated discharge at 0.33m, the discharge coefficient would be slightly lower, at 1.53, however the coefficient would be expected to rise with a rise in water level (and subsequent Head/Weir length ratio). The trapezoidal shape of the channel adds additional capacity that further makes the 1.65 coefficient acceptable. A stage discharge curve for the Naramata Dam spillway is shown in Figure 7-1.

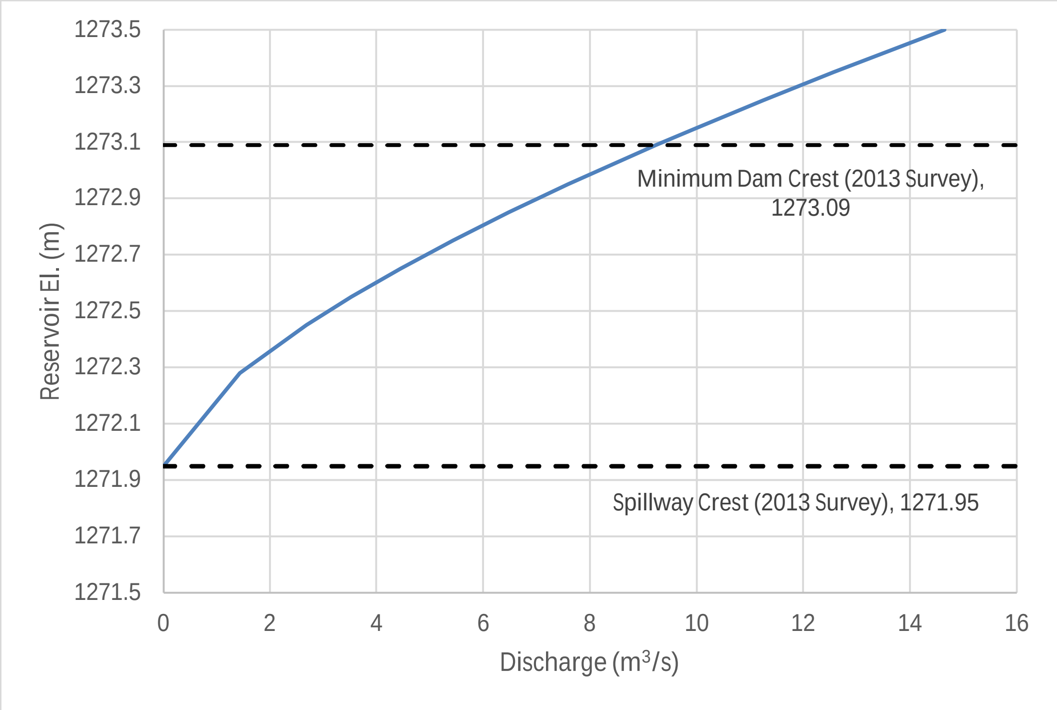


Figure 7-1: Naramata Spillway Stage-Discharge Curve

The spillway intake and outlet includes an excavated, grass-lined channel with some rock placement downstream of the spillway crest. The road to access the main dam crosses the upstream portion of the spillway (i.e. prior to flow passing over the crest). During the IDF, 4.6 m^3/s with 0.7 m of head and approximately 1.4 m/s will pass over the spillway. This velocity may damage an unprotected grass lined channel over time, however, it is unlikely to endanger the structure making this more of a maintenance issue. Additional studies could be completed for mitigation but are not likely required. It is recommended that any damage that occurs during such an event be repaired as soon as possible following such an event.

It is important to consider the repair of the road in front of the spillway to ensure that material is not placed higher than the spillway crest itself. This would effectively raise the spillway crest, lower the discharge capacity of the dam, and decrease the amount of freeboard available. (See Issue No. NL-5 in Table 13-1). The presence of this road is a concern for preserving the discharge capacity of the spillway. If the road elevation is at or above the elevation of the spillway weir, control will shift to the road, restricting outflows from the reservoir and potentially causing higher water levels during a flood event. Should this occur, it is likely that the road will erode to a point that control shifts back to the spillway but there remains a potential for this not to occur or that it may take a significant amount of time to occur. For this reason, in the short-term, careful attention should be paid to the road and repairs to it to ensure that this does not occur. In the longer-term, consideration should be given to replacing the road with a small bridge such as a bailey style or acrow style steel bridge and extending the excavated channel underneath. This will remove this potential and even if overtopped these types of bridges generally do not cause a great degree of flow reduction.

7.2.4 Flood Passage Capability

The discharge capacity of the Naramata Dam spillway was assessed in the dam breach study by Hatch (2021), which is summarized in a stand-alone report.

A hydraulic model was set up to route the flood through the system, and concluded that the spillway can pass the IDF (equivalent to an Annual Exceedance Probability of 1/3 between 1/1,000 and PMF, with a peak inflow of 4.4 m^3/s). The maximum reservoir water level during this event would be approximately 1272.67 m, which is 0.42 m below the minimum dam crest.

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, 2013a], 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 Naramata 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 700 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 Naramata 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: Naramata Dam Effective Fetch Calculations

Direction	Length (m)
N	695
NE	336
E	70
SE	16
S	5
SW	10
W	100
NW	234

Wind speed and direction data was taken from the Environment Canada climate gauge located at Summerland CS. This gauge is located approximately 13 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 Naramata 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 9.1 m, which ensured that deep water waves (conservative) were calculated.

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 N direction produced the most critical wave conditions 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 4H:1V. For wind setup (wind tide), the maximum length of the reservoir that was considered was determined to be 0.88 km. The impact of wind setup is expected to be extremely small for such a small reservoir, and indeed results in an approximate 1 cm setup 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 1271.95 m. For freeboard calculations, the still water level for the IDF was taken as 1272.67 m based on reservoir routing results shown in Section 7.2.4.

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 1272.81 m. Based on the 2010 Topographic Survey [EBA], the minimum crest elevation of the dams is 1273.09 m, meaning that there is 0.28 m of freeboard available. 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. NL-6 in Table 13-1).

Table 7-6: Freeboard Assessment Results (CEM)

Case	Direction	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 Minimum Crest Elevation (m)	Freeboard Remaining (m)
Extreme Wind (FSL)	N	1:1,000	0.7	50.1	1271.95	0.3	0.88	0.01	0.31	1272.26	1273.09	0.83
1/3 between 1,000-year and PMF Flood Passage	N	1:2	0.7	24.7	1272.67	0.14	0.88	0.00	0.1	1272.81		0.28

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 Naramata Dam. No riprap or erosion protection system was observed on the upstream dam face. A review of the existing photos taken during low water level shows the existence of granular materials on the upstream face.

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	0.05	0.16	0.1	0.3
10	0.07	0.21	0.1	0.3
20	0.07	0.23	0.1	0.3
30	0.08	0.24	0.2	0.3
50	0.08	0.26	0.2	0.3
100	0.09	0.28	0.2	0.3
1,000	0.11	0.35	0.2	0.4

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 0.2 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.

7.2.7 Ice and Debris

No records of debris problems at the structure have been found in the documentation.

A debris boom is in place upstream of the spillway to prevent debris accumulation at the site. Debris should be removed from this boom in a timely fashion in order to prevent excessive buildup and potential failure of the boom during a large flood event.

Due to the annual emptying of the reservoir prior to winter and its location far below the normal operating reservoir level, the intake is unlikely to experience any ice or debris issues.

7.3 Structural Assessment

7.3.1 General

As part of the DSR, the concrete structures at Naramata Dam site were reviewed for their condition and their capability to perform their intended functionality. Apart from the main embankment dam, the other water control structures include a concrete spillway weir, an intake structure and an outlet structure.

The intake is a relative low height structures with wide and stable base. Since this structure has performed reasonably well over its several years of operating life and no issues were reported, the stability of this structures is not a concern, as long as the structure is inspected and maintained.

For the Outlet structure, the retaining walls that support the downstream toe of the dam were checked for their capacity to withstand loading during normal operation and a seismic event. The Naramata Dam has been classified as a “Very High” consequence dam based on incremental consequences of failure. Under this consequence category, the seismic stability of the dam should be evaluated under an earthquake with a return period of 1/2 between 1/2,475 and 1/10,000 or Maximum Credible Earthquake (MCE) as described in the CDA Dam Safety Guidelines (CDA, 2013 revision). An average of 2,475 year and 10,000 year event was selected in this work. Correspondingly, a PGA of 0.110 g was used for earthquake loading calculations. Refer to Section 7.4.2 for additional details related to seismicity considerations. The tallest section of the retaining wall that supports the downstream face of the dam was checked as this was the critical section for loading. This wall section is 10’-6” high from the underside of the base slab. The bending moment and shear force capacity of this wall section was checked and was found to be adequate to withstand the loading during normal operation and an earthquake event.

The existing spillway is a trapezoidal shape structure with side walls sloping at 1.5H:1V, which are founded on side embankments. The middle section of the spillway weir is an inverted C-shaped concrete section with top slab and vertical shear keys at both ends. The vertical keys are 3 feet deep below the top slab and provide sliding stability to the spillway section. The upstream and downstream of the spillway are backfilled with riprap, as per the existing drawing No. 226-02-5. From the site visit, the spillway slab appears to be in stable condition as the structure is keyed into the riprap on both the upstream and downstream of the weir, and with lining along the sides of the channel. A center pier of concrete supported on the base slab also exists at the mid span of the spillway channel. The original structure had a provision to install stoplogs however the stoplogs are not used at this site and the spillway essentially operates as a free overflow section with no control elements such as gates or stoplogs.

A cursory review of the floatation/uplift stability of the spillway apron slab was performed. Since the spillway does not have any gates or stoplogs, any pressure at the underside of the apron slab is balanced with the flow above the slab. The floatation/uplift of the apron slab is not deemed a concern.

7.4 Geotechnical Assessment

Hatch conducted a geotechnical assessment of the Naramata dam as part of the 2020 DSR which included a review of available information on the original geotechnical design and related construction drawings, initial and supplementary field and laboratory investigations, site geology, design reports and as-built records. Information regarding the original dam design was not available. A background review based off the available information and the site visit observations made on July 9, 2020 (enclosed in Appendix A) was used to determine representative subsurface properties for the seepage and stability analyses. The results of the review and analyses are discussed herein.

7.4.1 Geology

A review of the previous DSR (EBA, 2010) and information from the Geological Survey of Canada Map Surficial Geology Kootenay Lake (1984) indicates that the dam foundation is likely comprised of sandy till overburden overlying crystalline metamorphic bedrock. The sandy till is described as an 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 between 5 m to 30 m (in valley troughs).

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 in EBA (2010), Figure 1.

7.4.2 Seismicity

The Naramata Lake Dam has been classified as a “Very High” consequence dam based on incremental consequences of failure. Under this consequence category, the seismic stability of the dam should be evaluated for a seismic return period of halfway between 1:2,475 years and 1:10,000 years as recommended in the CDA Dam Safety Guidelines (CDA, 2013a).

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 site.

The 2015 National Building Code of Canada (NBCC) seismic hazard calculator provides estimates of ground motion intensity measures for events up to and including 1:2,475 years. A site-specific probabilistic hazard analysis (PSHA) is typically utilized to determine intensity measures for seismic return periods greater than 1:2475 years. For this work, the 1:10,000 year peak ground acceleration (PGA) was estimated by performing a straight-line extrapolation on a log-log scale using the results from the NBCC seismic hazard calculator. Note that intensity measures obtained from extrapolation of the NBCC for long-return period events are preliminary, however, this extrapolation method generally returns conservative results. The NBCC hazard calculations and the variation in the PGA versus the return period are enclosed in Appendix B.

A PGA of 0.110 g was selected for this seismic stability analyses based on a PGA corresponding to the PGA halfway between 1:2475 years and 1:10,000 (CDA, 2013a). The horizontal seismic coefficient was assumed equivalent to the full PGA.

The variation in the PGA with respect to various return periods and previous versions of the NBCC are presented in Table 7-8 Note that PGAs between 2010 and 2015 have decreased due to new refinements in the 5th generation seismic hazard model utilized by the 2015 NBCC.

Table 7-8: Variation of PGA with Return Period

Return Period	PGA		
	NBCC 2005	NBCC 2010	NBCC 2015
1:100	0.034g	0.074g	0.010g
1:475	0.073g	0.072g	0.029g
1:1000	0.098g	0.098g	0.044g
1:2,475	0.138g	0.138g	0.070g
½ between 1:2475 and 1:10,000	**0.189g**	**0.189g**	**0.110g**
Extrapolated 1:10,000	0.239g	0.239g	0.148g

7.4.3 Preliminary and Supplementary Field Investigations

7.4.3.1 Geotechnical Investigations (Pre-1967)

Available historical geotechnical investigation information for Naramata Dam was limited, however, several drawings were provided which detail an investigation site plan, sections, and borehole logs for a geotechnical investigation which was carried out prior to construction of the 1967 upgrades. The purpose of the investigation was to identify borrow materials in areas upstream and downstream of the Naramata Dam and specially in the vicinity of the right abutment. Boreholes up to 13.4 m in depth (44’) drilled in this area encountered granular materials, slightly silty sand underlain by silty/clayey till. A list of drawings summarizing the 1967 geotechnical investigation at the dam site is provided below:

- T. Ingledow and Associates Ltd., 1967, “Naramata Lake Dam – Site Topography and Existing Dam”, Drawing 226-02-2.

- T. Ingledow and Associates Ltd., 1967, "Naramata Lake Dam – Borrow Areas – Plan and Sections", Drawing 226-02-6 and -7.

Notably, no in-situ testing was reported in any of the boreholes and information on drawings are limited to subsoil stratigraphy and associated thickness.

7.4.3.2 *Embankment Dam*

The Naramata Dam was constructed and raised in two stages. The original dam was constructed at the confluence of two valleys comprised of two embankments (east and west) in dates spanned from 1912 to 1937 (OMS, 2017). The dam was later raised and combined into one dam in 1967.

The original dams were comprised of homogenous, low permeability fill with a maximum embankment height of approximately 3.5 m. In 1937, the dams were raised to a maximum height of approximately 6.1 m with the placement of additional low permeability fill.

In 1967, the dam was substantially rebuilt as a zoned earth dam, comprising a low permeability upstream blanket, a granular downstream shell, and a downstream foundation filter incorporating pipe drains with a maximum height of 10.7m. The existing drawings of the dam indicate that it has a 4H:1V upstream slope and 3H:1V downstream slope. Figure 7-2 provides two typical cross sections of the Naramata Dam following the 1967 dam raise and also outlines the location of the existing piezometer and location of the boil identified in July, 2020.

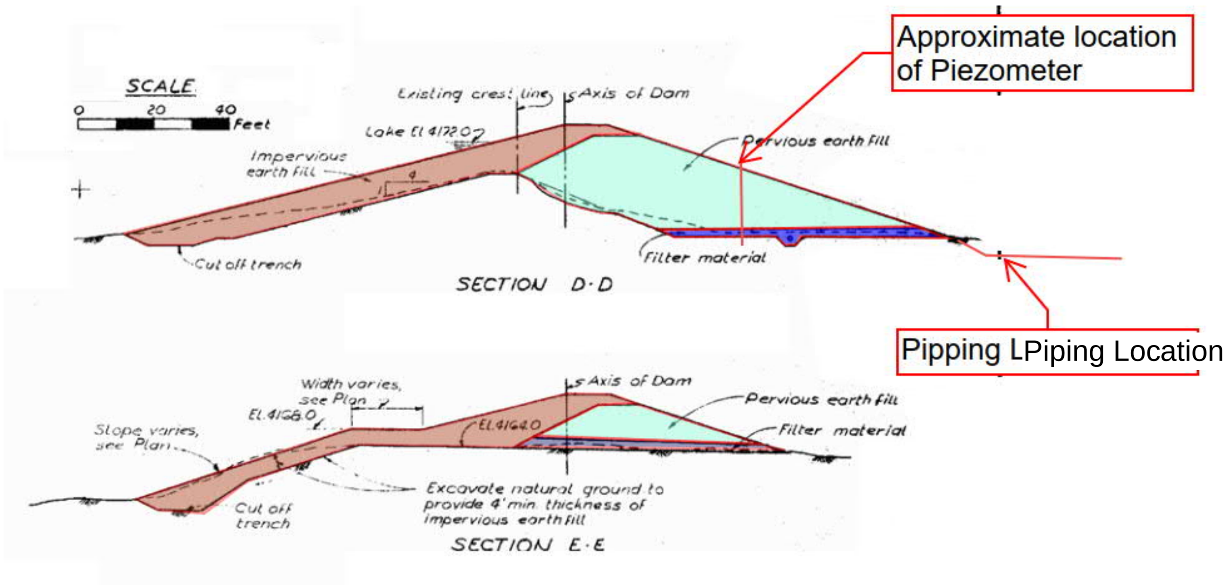


Figure 7-2: Naramata Dam Typical Cross Sections

7.4.3.3 Recent Construction

A comparison of a historical site plan (Drawing 226-02-3 R1) and recent surveys suggest that the downstream area of the Naramata Dam has been reworked to a new configuration as shown in Figure 7-3 where the downstream slope is significantly flatter than 4H:1V. During the new construction, a new piezometer was added shown as shown in Figure 7-3.

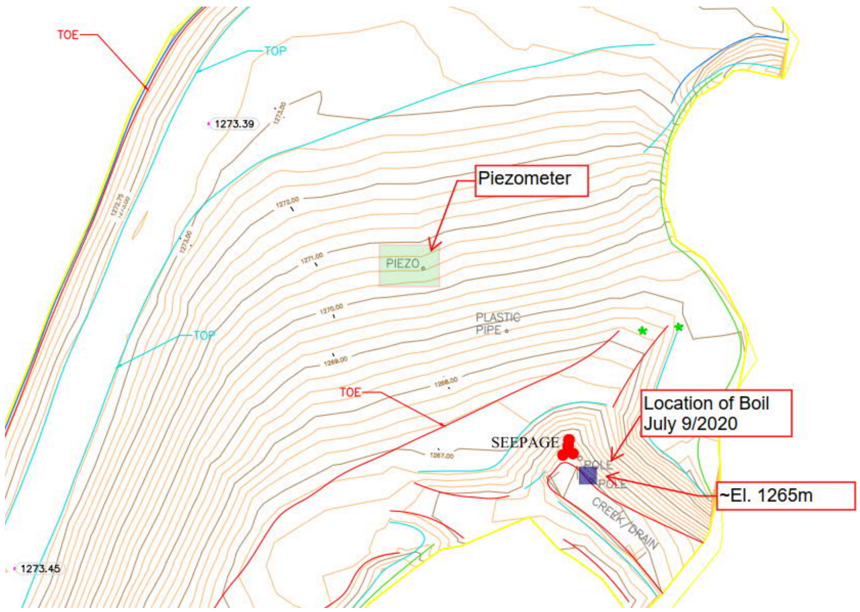


Figure 7-3: Naramata Dam Downstream of Left Abutment

7.4.3.4 Spillway

Original construction drawings (Drawing 226-02-5R1) indicate that the spillway is excavated in the natural materials on the right side of the Naramata Dam connecting to Robinson Creek on the downstream side, approximately 100 m to 120 m (350’ to 400’) downstream of dam axis. A spillway weir was designed immediately downstream of the dam crest comprised of a concrete slab and shear keys.

No fill placement was observed for erosion protection in the form of riprap or riprap bedding on drawings, other than a limited area 6 m (20’) immediately downstream of the spillway weir which could be found during the 2020 site inspection by Hatch.

Various cross sections at the location of the spillway indicate that the spillway foundation is comprised of silty sand, gravels and cobbles underlain by silty/clayey till.

7.4.3.5 Foundation

Information of the foundation materials at the Naramata Dam site is limited what is available is presented as follows:

Right abutment:

Based on the existing information, the foundation from the ground surface is primarily comprised of:

- Surficial organics and peat
- Upper granular layer, comprised of variable quantity of sand and gravel, cobbles and boulders and silt
- Clayey to silty till.

Dam Alignment:

The foundation materials, from surface, are generally comprised of:

- Organic / peat at the surface
- Clean coarse sand and gravel
- Silt and fine sand
- Cobbles and boulders.

It should be noted that the above ground stratigraphy detailed above are based on historical information with limited in-situ and laboratory testing. Limited information exists related to method of drilling and no report exists describing the findings.

7.4.4 Seepage and Slope Stability Assessment

Seepage and slope stability assessments of the main dam were performed as part of the Hatch 2020 DSR. The analyses were undertaken with a specific focus on the occurrence of boils at the downstream dam toe and its representative phreatic surface within the dam. EBA (2010) noted that seepage at the downstream toe of the dam is a commonly observed occurrence; previous dam inspections have concluded that toe seepage occurs primarily due to foundation seepage flows.

The following reports, drawings, and data provided by RDOS were used to develop the cross-section geometries and material properties:

Geometries:

- EBA Engineering Consultants Ltd. Topographic Survey of Naramata Dams. January, 2013. (DWG No. ES-01).

Materials:

- EBA Engineering Consultants Ltd. Big Meadow Lake Dam Geotechnical Assessment. January, 2013.

Two sections were analyzed for the seepage and slope stability assessments: as shown in Figure 7-4 the first in the area where boils were noted downstream during the site inspection (Section A) and the other section in the area of the low level outlet (Section B). Section B is the critical section for seepage and slope stability, however Section A was also analyzed because of the historical seepage observations.

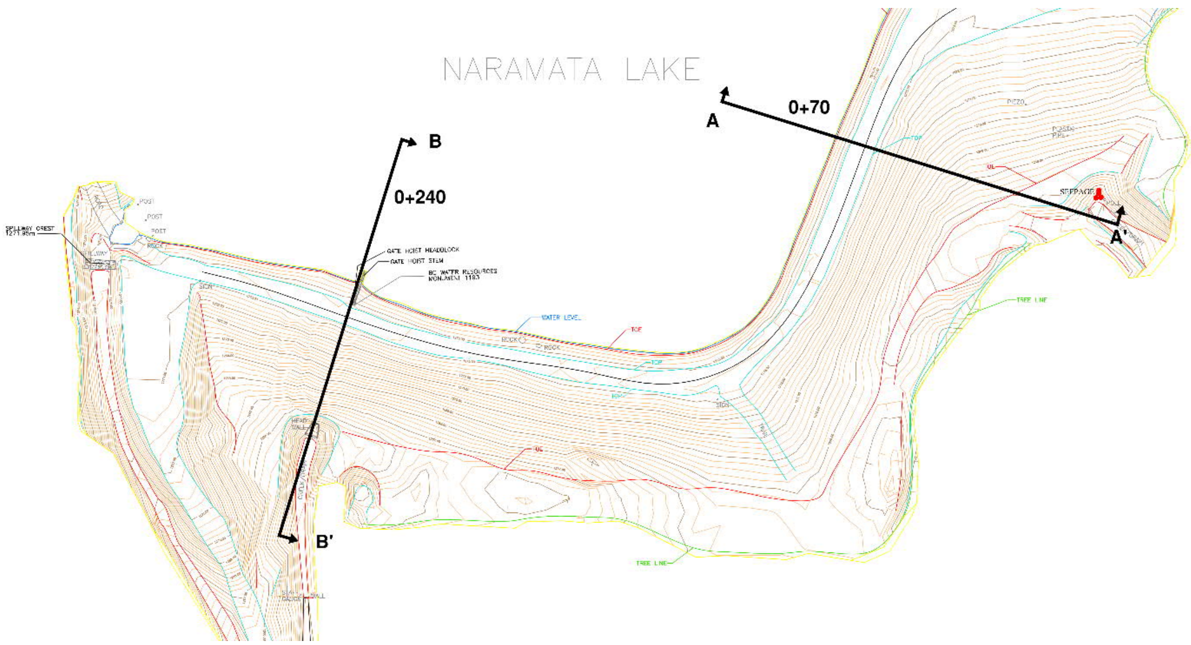
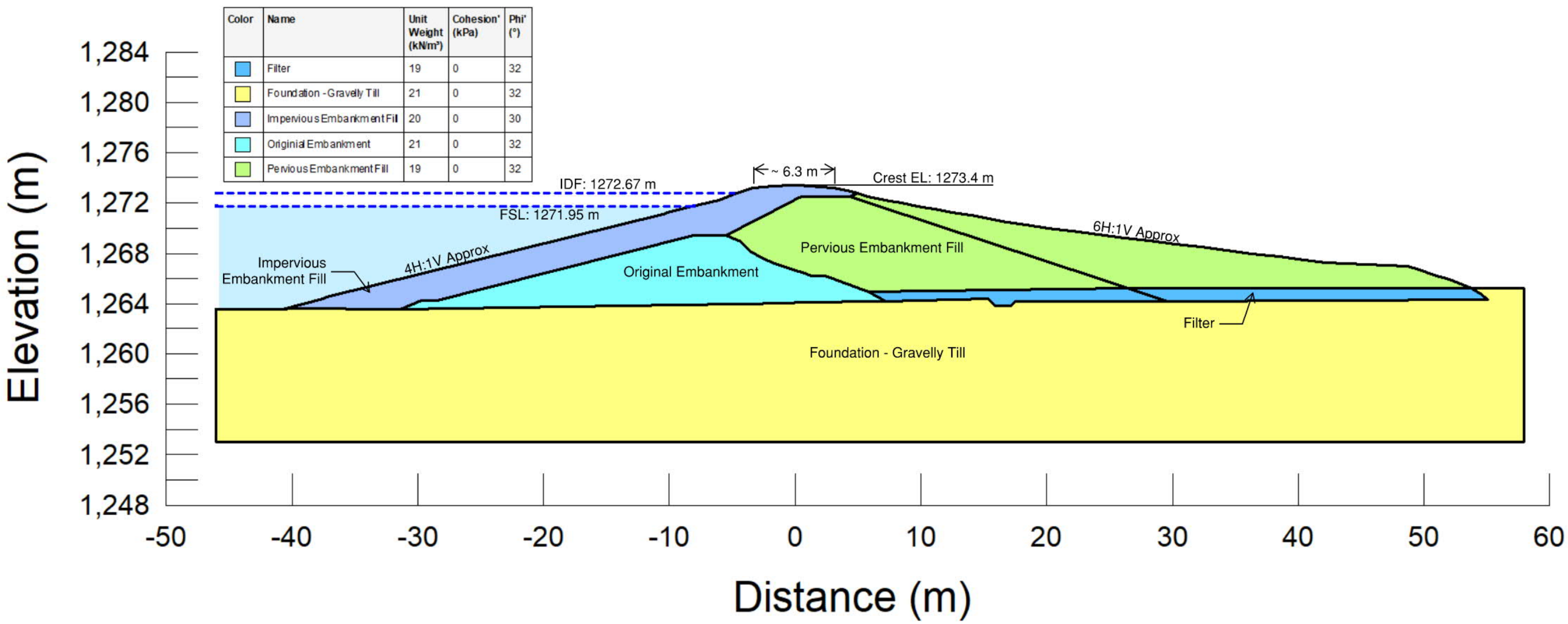


Figure 7-4: Assessed Seepage Sections (adapted from EBA, 2013)

A typical cross section for the slope stability and seepage analysis for Section A is presented in Figure 7-5, and Section B in Figure 7-6



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Filter	19	0	32
	Foundation - Gravelly Till	21	0	32
	Impervious Embankment Fill	20	0	30
	Originial Embankment	21	0	32
	Pervious Embankment Fill	19	0	32

Figure 7-5: Typical Section of Naramata Dam Section A

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Filter	Mohr-Coulomb	19	0	32	0
	Foundation - Gravelly Till	Mohr-Coulomb	21	0	32	0
	Impervious Embankment Fill	Mohr-Coulomb	20	0	30	0
	Original Embankment	Mohr-Coulomb	21	0	32	0
	Pervious Embankment Fill	Mohr-Coulomb	19	0	32	0

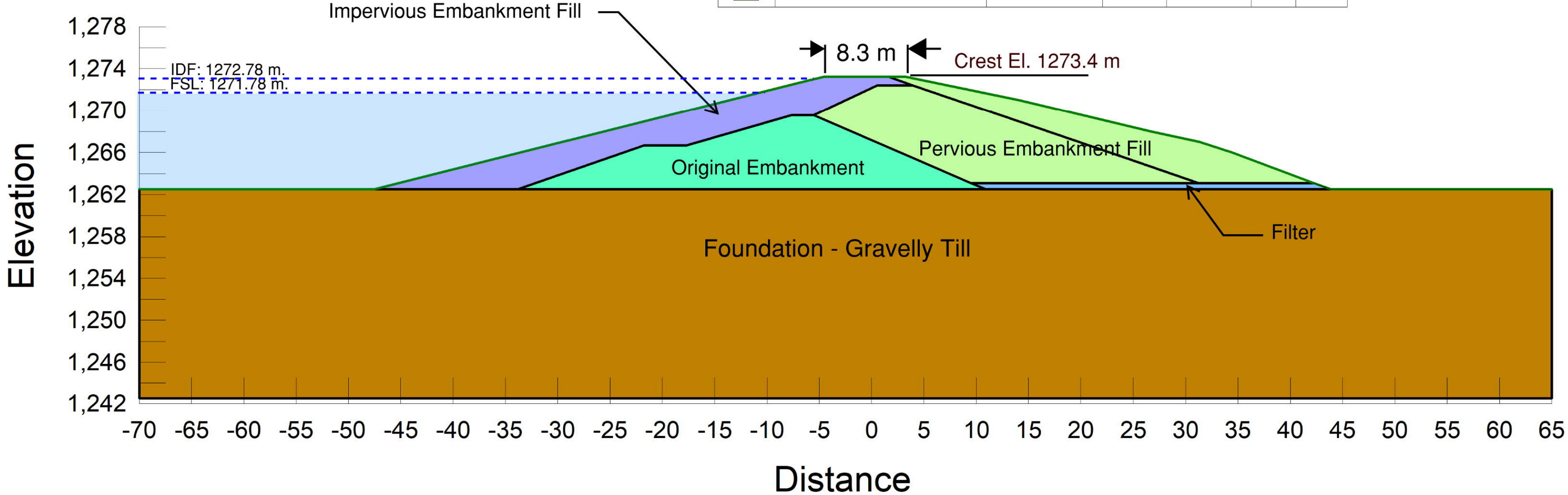


Figure 7-6: Typical Section of Naramata Dam – Section B

7.4.4.1 *Material Parameters*

No historical investigation information or laboratory testing was available to assist with the selection of material permeabilities. Accordingly, material permeabilities were selected based on the results of in-situ testing at the nearby Big Meadow dam, literature review, and Hatch engineering experience. The primary objective of the seepage model was to estimate hydraulic exit gradients and seepage quantities at the dam toe.

The material parameters were further calibrated based on measurements from the downstream dam piezometer and suspected high exit hydraulic gradients near the dam toe which likely attributed to boil formation. The selected seepage parameters are summarized in Table 7-9.

Table 7-9: Seepage Material Properties – Hydraulic Permeability

Materials	Hydraulic Permeability (m/sec)
Embankment Fill	1×10^{-6}
Filter	1×10^{-6}
Upstream Low Permeability Blanket	1×10^{-8}
Foundation Till	1×10^{-6}

Material strength parameters for the slope stability analysis were selected based on the results of in-situ testing at the nearby Big Meadow dam, literature review, and Hatch engineering experience. The selected strength parameters are summarized in Table 7-10.

Table 7-10: Material Parameters for Slope Stability Assessment

Materials	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)
Gravelly Till Foundation	21	32	0
Upstream Low-permeability Fill	20	30	0
Pervious Embankment Fill	19	32	0
Filter	19	32	0

7.4.4.2 *Seepage Analysis*

The seepage analysis was performed using SEEP/W software developed by GEO-SLOPE International Ltd. Version 10.1.1.18972.

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

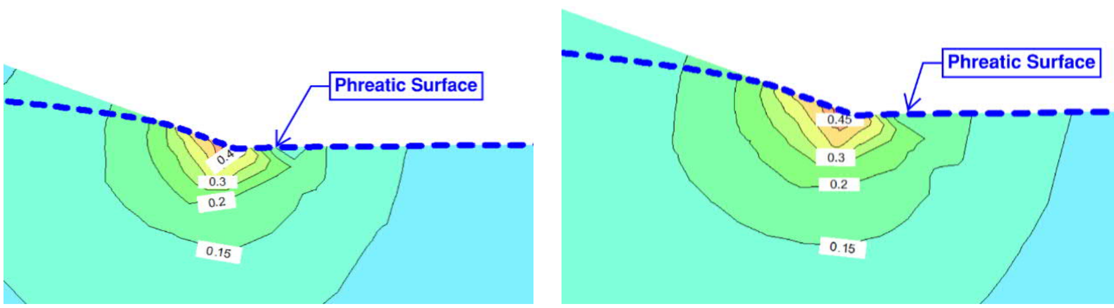
- Full supply level (FSL): 1271.95 m
- Inflow Design Flood (IDF): 1272.67 m

It should be noted that although IDF conditions are transient and generally do not constitute a steady-state condition, the July 2020 downstream boil was observed during a relatively long duration of high reservoir elevation (Hatch, 2020). To be conservative we assumed that the IDF level would be sustained long enough to achieve steady state, although Hatch concurs that this will not be the case.

The results of a seepage analysis of the existing dam are enclosed in Appendix C; a summary of the estimated exit gradients and seepage quantities are presented in Figure 7-7 and Table 7-11.

Section A

FSL *IDF*



Section B

FSL *IDF*

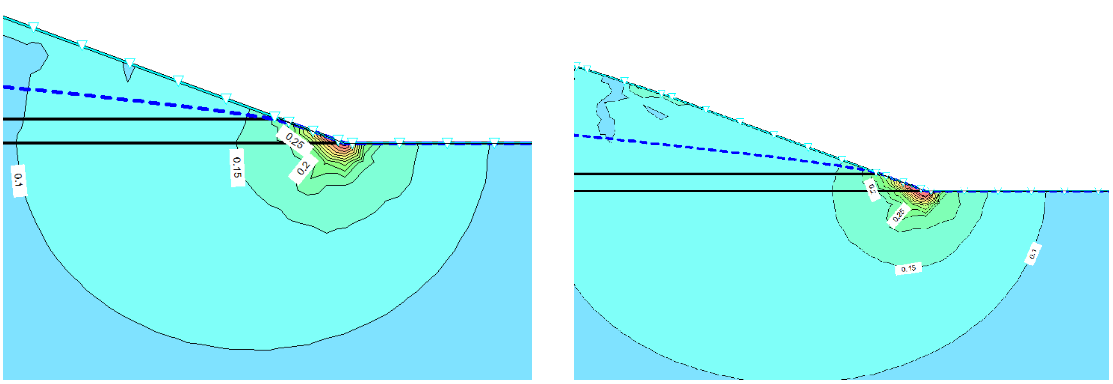


Figure 7-7: Distribution of Exit Seepage Gradients at Existing Dam Toe

The results of the seepage analysis indicate estimated vertical seepage gradients of up to 0.45.

Table 7-11: Results of Steady State Seepage Analysis for Existing Dam

Analysis	Estimated Maximum Exit Gradient (*i*)	Seepage Quantity
Section A		
FSL	0.40	2.5 m^3/day/m
IDF	0.45	3 m^3/day/m
Section B		
FSL	0.75	14.5 m^3/day/m
IDF	0.89	3 m^3/day/m

The 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:

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

The factor of safety against piping at Naramata Dam is estimated to range between 1.9 to 2.75, at Section A, and between 1.1 and 1.33 at Section B. However, boiling has been observed at Section A and not at Section B. It is likely that foundation conditions are less favorable in the vicinity of the boil. The geotechnical parameters used in the analysis were preliminary, and a geotechnical investigation should be completed to characterize foundation conditions more fully.

Allowable factors of safety against piping typically range between 2 and 4 as outlined in Table 7-12.

Table 7-12: 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 analyses indicate the following:

- The calculated factor of safety at Naramata dam may be lower than is generally recommended.

- The estimated exit gradients between 0.40 and 0.45 are approximately equivalent to an exit gradient of 0.5 at which boil formation has historically occurred (USACE, 2005).
- The seepage parameters required to obtain the estimated exit gradients and approximately match the downstream piezometer reading suggest that the granular foundation till and dam filter have similar permeabilities. This reduces the ability of the filter to intercept seepage and reduce downstream gradients. This may occur due to:
  - Foundation heterogeneity, i.e., the presence of permeable layers within the foundation which result in lower head loss and higher exit gradients.
  - Clogging of the filter layer.

It should be noted that the calculated gradients and factors of safety are estimates only and given historical performance observations may be subject to change as additional information regarding the material permeabilities and foundation characteristics is obtained.

The seepage analysis was repeated with the addition of a pressure relief drain at the downstream dam toe which extends to a depth of 2 m below grade. The drain includes an approximately 1.5 m tall overlying riprap berm which applies vertical surcharge pressure and provides resistance against boiling and heave. The objective of the relief drain is to intercept seepage and hydraulic gradients below grade to mitigate the initiation of boiling and piping at the surface. High exit gradients may still exist below the drain, however, their disruptive effects will be balanced by the overburden pressure of the relief drain.

The results of the seepage analysis including the relief drain are enclosed in Appendix C; a summary of the estimated exit gradients and seepage quantities are presented in Figure 7-8.

FSL *IDF*

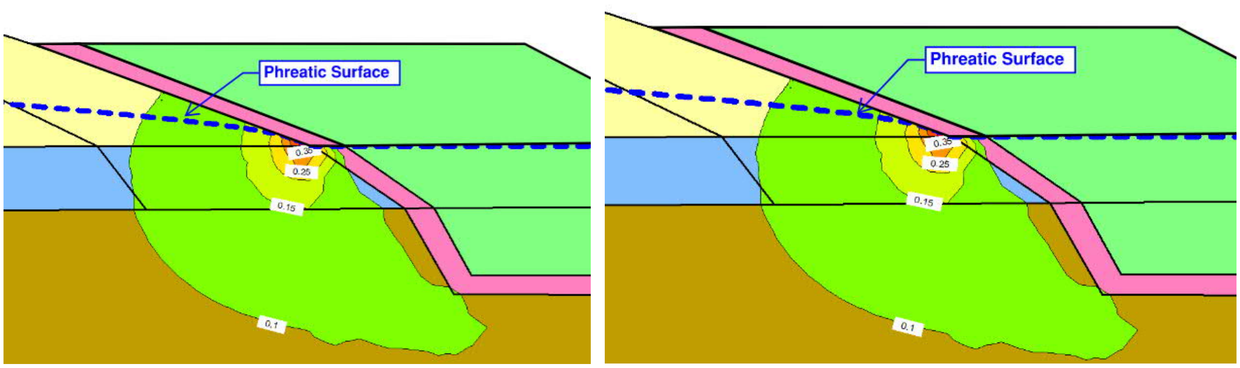


Figure 7-8: Distribution of Exit Seepage Gradients with Relief Drain

The results of the seepage analysis indicate that the provision of a relief drain which intercepts seepage below grade is likely to be an effective mitigative measure against boil and piping initiation at the downstream dam toe. The relief drain significantly reduces exit gradients beyond the dam toe and large exit gradients are driven to a deeper depth. The overlying riprap berm applies vertical surcharge pressure to the concentrated exit gradients at the dam toe which protects against boiling and heave. It is recommended that these assessments will be updated once a geotechnical investigation and piezometers installation is conducted. (see Issue No. NL-2, 3, 7, 12 in Table 13-1)

A design of a downstream relief drain should consider the following:

- A geotechnical site investigation should be performed to better understand the dam and foundation composition
- Construction of a riprap berm for additional erosion protection of the downstream dam face and to apply vertical surcharge pressure on the native foundation.
- Use and selection of both a granular filter and bedding material to transition between the finer embankment fill and more coarser riprap toe, and, to prevent clogging.
- Sensitivity analysis of the required drain depth.

7.4.4.3 Slope Stability Analysis

Slope stability analyses were performed using the limit-equilibrium method (LEM) SLOPE/W software developed by GEO-SLOPE International Ltd, Version 10.1.118972. The analysis was performed using the Morgenstern-Price method of slices with a half-sine inter-slice force function.

Slip surfaces were generated using the entry and exit method which assesses slip surfaces within the specified slip-entry and slip-exit domains.

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 7.2.4 and 7.4.2, respectively. The slope stability load cases are summarized in Table 7-13.

Table 7-13: Loading Conditions for Big Meadow Lake Dam Section

Load Case	Operating Conditions	Remarks
LC-1	Normal Load Condition - Full Supply Level (FSL)	Reservoir Elevation = 1271.95 m
LC-2	Flood Condition - Inflow Design Flood (IDF)	Reservoir Elevation = 1272.67 m
LC-3	Rapid Drawdown (RDD)	Reservoir Elevation = 1263.6 m*
LC-4	Seismic	Horizontal seismic coefficient (kh) of 0.11g corresponding to the full PGA of the EDGM**.

* Corresponds to reservoir floor elevation due to limited drawdown information.
** EDGM defined as average of 1:2,475 year and 1:10,000 year seismic events (CDA, 2013a)

The results of the slope stability analyses for the assessed load cases are presented in Table 7-14 output from SLOPE/W is enclosed in Appendix D.

Table 7-14: Results of Stability Analyses

Load Condition	Required Minimum Factor of Safety	Factor of Safety Normal Loading Conditions	
		Upstream	Downstream
Section A			
LC-1 (FSL)	1.50	2.67	3.35
LC-2 (IDF)	1.30	2.69	3.23
LC-3 (RDD)	1.20 - 1.30	1.39	N/A
LC-4 (Seismic)	1.00	1.41	1.81
Section B			
LC-1 (FSL)	1.50	3.90	2.17
LC-2 (IDF)	1.30	4.27	2.12
LC-3 (RDD)	1.20 - 1.30	1.34	N/A
LC-4 (Seismic)	1.00	2.08	1.44

The results of the stability analyses indicate that the dam exceeds the minimum CDA recommendations for all load cases except the rapid drawdown condition. It should be noted that CDA recommendations for the minimum factor of safety during rapid drawdown range from 1.20 to 1.30. The lower bound corresponds to dams where rapid drawdown is a rare occurrence. Hatch recommends a minimum factor of safety of 1.30 for rapid drawdown conditions due to the frequency of drawdown and 'Very High' consequence rating of the dam.

The historical performance of Naramata dam has not indicated any slopes instability which is reflected in the calculated factors of safety in Table 7-14, however, future remedial works should consider provisions for upstream slope erosion protection reinforcement such as an upstream riprap blanket.

7.4.5 Liquefaction Considerations

Available information regarding subsurface conditions was not available at the time of writing this report. Accordingly, no quantitative liquefaction assessments were undertaken for Naramata dam. A seismic assessment of the dam is recommended due to its "Very 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. (see Issue No. NL-4 in Table 13-1).

7.4.6 Internal Instability Assessment

Internal erosion refers to the migration of fine soil particles within the coarser soil matrix which may result in the formation of voids, increased permeability, and potential piping. The migration of fine soil particles is typically triggered by large hydraulic gradients and/or flow velocities. Materials susceptible to internal erosion are typically gap-graded or poorly graded.

The Li-Fannin (2009) method is widely employed method of determining the internal erosion susceptibility of a soil based on its grade size distribution. It should be noted however that internally unstable soils must be subject to destabilizing hydromechanical forces for internal erosion to occur.

The Li-Fannin assessment was not undertaken for Naramata Dam as no soil gradations were available for analysis. A geotechnical investigation should be undertaken to classify the dam and foundation materials and collect laboratory samples for grain size analysis. (see Issue No. NL-2, 7, 12 in Table 13-1).

7.4.7 Piping Risk Assessment

EBA (2009) indicated that no reliable filter appears to be present upstream or downstream of both the East Dam and West Dam cores. Past inspections (including the most recent 2009 inspection) have not specifically identified the presence of turbid seepage downstream of each structure. It should be noted however that this may be a result of sampling bias as past inspectors may not have undertaken comprehensive turbid seepage monitoring during their investigations. Although historical dam performance suggests that turbid seepage has not occurred to date, the dam operators and future inspectors should be cognizant of potential future turbid seepage that may occur. Regardless, historical dam performance suggests that the replacement of the old West Dam CMP spillway with the newer well-constructed concrete box inlet spillway has likely reduced the risk of piping susceptibility that may have existed due to the seepage path caused by the buried CMP which is one (1) of the most common major piping failure modes.

As part of this DSR, Hatch repeated the piping risk assessment for both dams as carried out by EBA (2009), given the new condition and relating the risks presented by dams considering the “High” DFCC.

The method used is based on the formulated by Foster and Fell (2000). 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 and Fell (2000) for a more detailed explanation of the methodology.

The piping risk assessment for the East and West Dams was performed using identical input parameters. Although the East and West dams are constructed with different elevations, the dams share similar consequence classifications, design concepts, construction schemes, and overall configurations. The various assumptions utilized in the Foster and Fell (2000) analysis at the dams for the three discussed failure types are presented in Table 7-15 though Table 7-17. References for the selected weighting factors are provided in Figure 7-9 through Figure 7-11. Annual failure probabilities applicable to both dams are presented in Figure 7-12 and Figure 7-13.

Table 7-15: Foster and Fell (2000) Coefficients for Piping through both Embankments

Factor	Factor Description	Score	Commentary
Embankment Filters	No embankment filter (for dams that usually have filters;	2	No filter can be confirmed
Core Geological Orogin	Residual, lacustrine, marine, volcanic	1	Materials were utilized from the reservoir footprint. Not enough information to confirm as glacial till.
Core Soil	Clayey and silty sands (SC, SM)	1.2	Silt and Sand
Compaction	Rolled, modest control	0.5	Some level of compaction was assumed
Conduits	Conduit through embankment, typical USBR practice	1	Spillway conduit has been built.
Foundation Treatment - Bedrock	Irregularities in foundation or abutment, steep abutments	1.2	Modest prep was considered.
Observations of seepage	Leakage steady, clear, or not observed	1	
Monitoring and surveillance	Weekly–monthly seepage monitoring, weekly inspections	0.8	Weekly inspection.
Type of Embankment	Cenrtal core earth and rockfill		
Age in years	50		
Embankment type factor	34		
	W_E =	1.152	Embankment Weighting Factor
	P_E =	3.40E-05	Cenrtal core earth and rockfill
	The East/West Embankment Probability =	3.92E-05	Annual

Note: USBR refers to US Bureau of Reclamation

Table 7-16: Foster and Fell (2000) Coefficients for Piping through both Foundations

Factor	Factor Description	Score	Commentary
Foundation Filters	No foundation filter present	1	Filter is not present between core and bedrock
Foundation below cutoff	not applicable	1	Not used.
Cut-off (soil foundation)	Shallow or no core trench	1.2	No core trench exists
Cut-off (rock foundation)	Average cut-off trench	1	No cutoff constructed
Soil Geology below condut	Alluvial	0.9	not applicable
Rock Geology (below cut-off)	Sandstone, shale, siltstone, claystone, mudstone, hornfels	0.7	no cutoff
Observations of seepage	Leakage steady, clear or not observed	1	No leakage or very small noted during insepctions.
Observations of pore pressure	Low pressures in foundation	0.8	No abnormal pore pressure occurences in foundation
Monitoring and surveillance	Weekly–monthly seepage monitoring, weekly inspections	0.8	
Embankment type factor	19		
	W_F =	0.484	Foundation Weighting Factor
	P_F =	1.90E-04	Cenrtal core earth and rockfill
	The East and West Dams Foundation Probability =	9.19E-05	Annual

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

Table 7-17: Foster and Fell (2000) Coefficients for Piping of Embankment into both Foundations

Factor	Factor Description	Score	Commentary
Filters	Appears to be independent of presence–absence of embankment or foundation filters	1	No filter between embankment and foundation
Foundation cutoff trench	Shallow or no trench	0.8	Not applicable
Foundation	On or partly on soil	1	Partly on rock
Erosion control measures of core foundation	None, open jointed bedrock or open work gravel	3	
Foundation Grouting	None on rock foundation	1.3	None
Soil Geology Types	Glacial	1.5	assumed West Dam, glacial silt
Rock Geology	Sandstone, conglomerate	0.8	
Core geological orogin	Residual, lacustrine, marine, volcanic	1	Could be alluvial?
Core soil type	Caly or silty sand (SC or SM)	1.2	
Core compaction	Appears to be idependent of compaction	1	Assumed to be adequate
Foundation Treatment (rock)	Irregularities in foundation or abutment, steep abutments	1.1	
Observations of seepage	Muddy leakage, sudden increases in leakage	3	No measurable/observable seepage of embankment into foundation. May be increasing with some sinkholes could have formed in the past
Monitoring and surveillance	Weekly–monthly seepage monitoring, weekly inspections	0.8	
Embankment type factor	4		
	W_{EF} =	11.861	Embankment Weighting Factor
	P_{EF} =	4.00E-06	Cenrtal core earth and rockfill
	The East and West Dams Embankment piping into Foundation Probabiity =	4.74E-05	Annual

	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 7-9: 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 7-10: Weighting Factors (Values in Parentheses) for Piping through the Foundation Mode of Failure

	General factors influencing likelihood of initiation of piping				
Factor*	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 7-11: Weighting Factors (Values in Parentheses) for Accidents and Failures as a Result of Piping from the Embankment into the Foundation

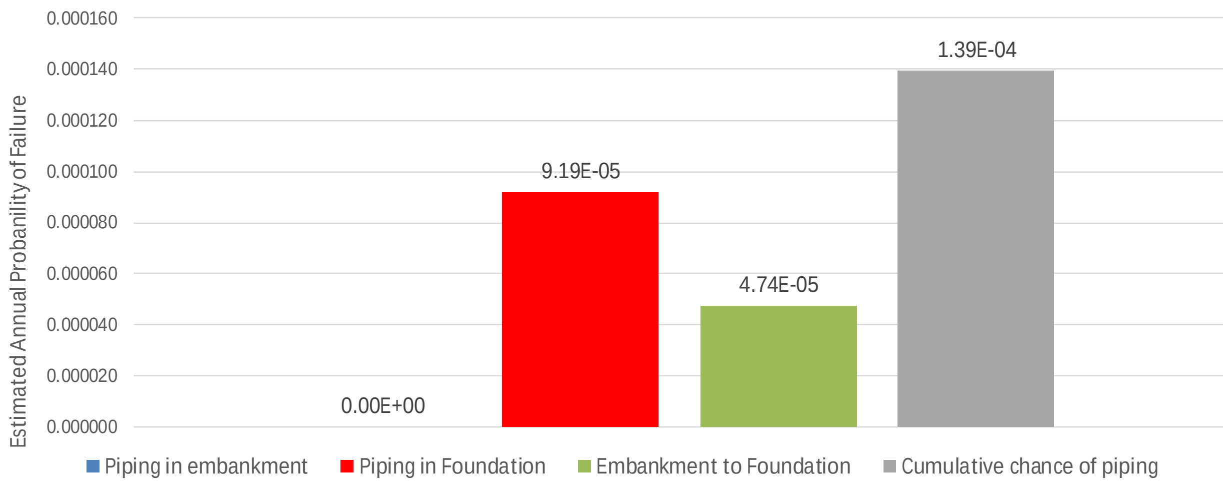


Figure 7-12: Estimated Annual Probability of Failure of the Naramata Lake Earthfill Dams Using Foster and Fell [2000]

According to CDA Guidelines (CDA, 2013a), the life safety risk should be consistent with accepted practice in other high hazard industries and with the understanding that risks should be made as low as reasonably practicable (ALARP). Using this approach, a better understanding of the piping risks can be obtained by plotting the annual exceedance probability against the expected number of persons subjected to a Life Safety Risk. Figure 7-13 outlines the piping risk with regards to life safety risk using the DFCC of "Very High" and assuming a potential for Loss of Life.

The red, yellow, and green bands represent unacceptable, tolerable (if 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 for the East and West Dams ranges between tolerable (if ALARP) and unacceptable.

Several measures may be considered to reduce the piping risk. The risk acceptance is highly sensitive to the number of persons subjected to a life safety risk. Therefore, undertaking the suggested improvements to the dam and developing a more comprehensive public warning and evacuation plan may provide a more favorable risk rating which categorizes the risk as tolerable (if ALARP). Additional measures may include supplementary training and instructions to Dam Operators to properly identify, sample, and respond to seepage turbidity. Seasonal turbidity laboratory tests may then be conducted on any water samples taken (see Issue No.12 and All-5 and in Table 13-1).

Structural mitigation may include the construction of piping control measures such as a reverse filter blanket at the toe of the dam(s).

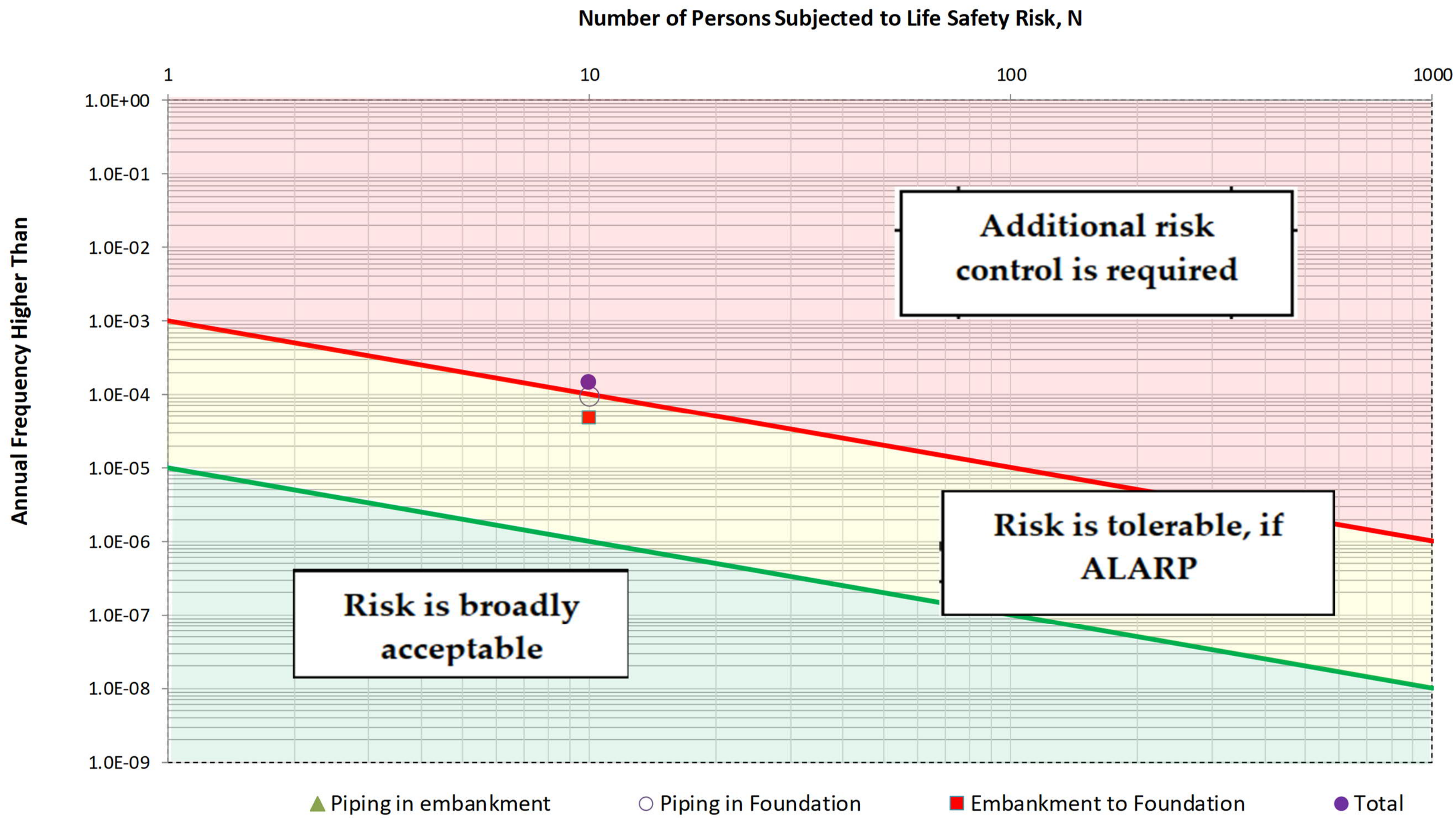


Figure 7-13: Existing Risk Acceptability for the Naramata Dam Considering VERY HIGH DFCC

7.4.8 Geotechnical Assessment Conclusions and Recommendations

Recommendations arising from the results of the Geotechnical Assessment include the following (see Issue No. NL-2, 3, 4, 7, 12 in Table 13-1):

- There is a lack of site-specific geotechnical information available for Naramata Lake Dam. The lack of information prevents a complete assessment of the geotechnical conditions. A geotechnical investigation consisting of boreholes and in-situ and laboratory geotechnical testing should be conducted to fully characterize the materials of the embankment and foundation.
- There is history and evidence of boiling which indicates potential piping in the foundation. This was supported by results of the seepage analyses. Remedial works such as a filtered toe berm should be considered upon completion of the geotechnical investigation.

7.5 Mechanical Assessment

The only control equipment at the site is the gate on the riparian conduit

The gate itself is a 0.76 m square sliding gate manually controlled with a screw stem. . The estimated capacity of this gate is 0.42 m^3/s at FSL. The gate is in generally good condition and is able to provide control for the reservoir as originally intended. This gate is not meant for and generally should not be used for flood control purposes. No further issues concerning dam safety were identified with the gate or mechanism. It should continue to be maintained in good working order and monitored for deterioration and leakage.

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

Naramata 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, indicating the presence of the public on this structure. While this is not an immediate concern, it indicates 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, a locked outlet gate preventing public operation of the gate, and a log boom in front of the spillway restricting access to the spillway directly from the lake.

8.2 Public Safety Management Plan Audit

RDOS does not currently have a comprehensive public safety management plan in place for Naramata 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 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.

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

8.2.2 Riparian Conduit Structure

The Risk Control Survey recommends barriers at the low flow outlet structure as fall protection.

During the site visit it was noted that the riparian conduit wheel is locked and therefore restricted from public operation, however there is no signage warning the public of danger.

No warning signs or buoys are present around the riparian conduit inlet to indicate the presence of a submerged inlet. The inlet is deep enough below FSL that it is unlikely a vortex would form that could affect boaters at the water surface. However, swimmers or other users should be alerted to the presence of potentially dangerous currents in this area of the dam. Although the risk control survey made some good recommendations, it is recommended that a brief supplemental public safety risk analysis and assessment in accordance with CDA Guidelines be undertaken to determine the need and form of signage and safety buoys that may be required in this area.

8.2.3 Spillway

The Risk Control Survey generally recommends signage, as indicated above, which could pertain to this area.

The spillway structure is accessible using the gravel access road that crosses the inlet channel to the spillway structure and continues across the dam crest. The main concern would occur when the spillway is activated, and flow is crossing the access road to the dam crest. No warning signage was observed at the approach to the spillway inlet at the access road crossing for this purpose.

There is a debris boom at the approach to the spillway inlet. No warning signs were observed in the spillway approach channel to warn boaters or swimmers to stay away from the spillway. No warning signs were present along the approach channel for pedestrian or road access.

It is recommended that a brief supplemental public safety risk analysis and assessment in accordance with CDA Guidelines be undertaken to determine the need and form of signage and safety control measures that may be required in this area.

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.

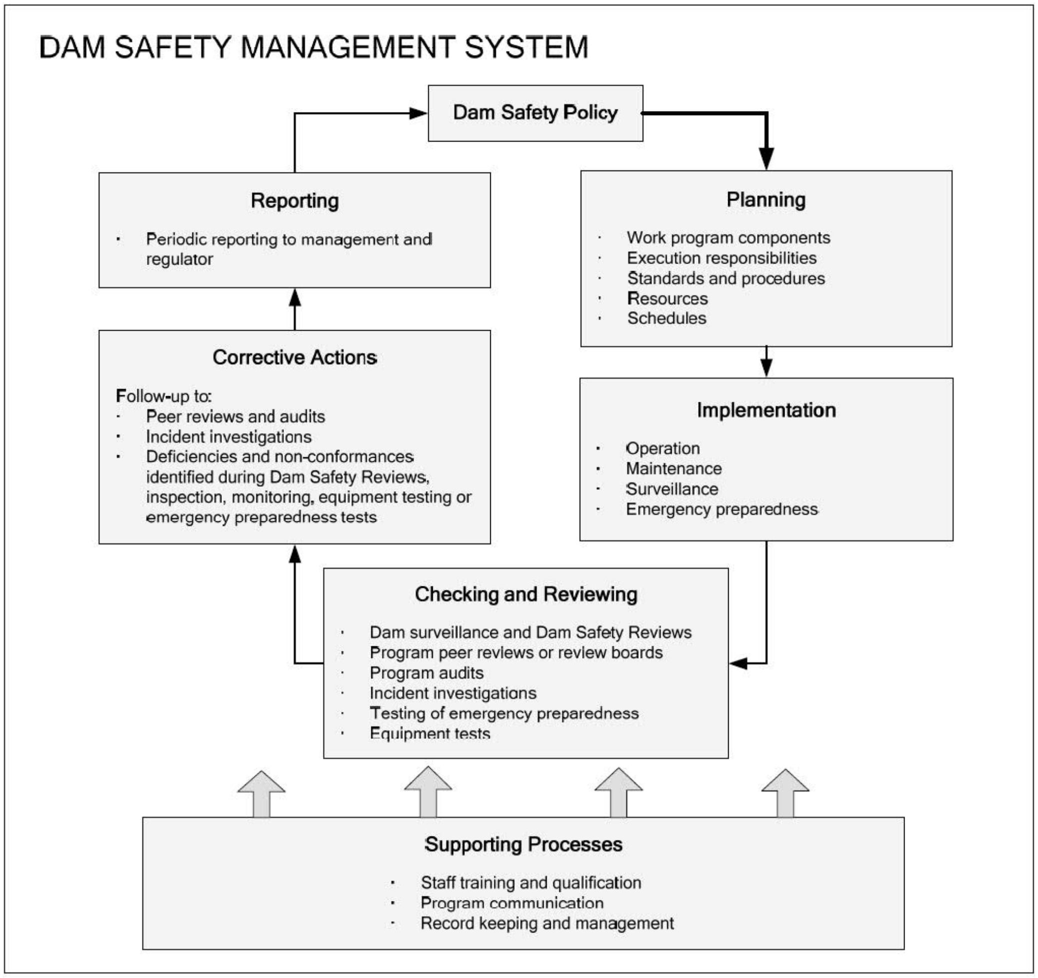


Figure 9-1: Overview of a Dam Safety Management System

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.

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

Naramata 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 Naramata 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 Naramata Dam are outlined in the following sections.

10.1 Operation

10.1.1 Normal Operations

The OMS manual produced as part of this project provides adequate information of monitoring and operation of Naramata 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*

As the spillway includes a weir with no control gates, there are generally no flood operations associated with the Naramata Spillway.

A marking system along the gate hoist stem is available to measure water levels. Regular recording of water levels is noted by RDOS in their Routine Dam Inspection Reports. These are recorded weekly as per regulation during the high-water period. 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. A rating curve was added to the OMS Manual during this study. 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 Naramata 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 Naramata 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).

In this case it is 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. 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. NL-11 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, outlet works, spillway channel, instrumentation 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.

It is recommended that an automatic water level gauge be installed on Naramata Lake, calibrated and regularly maintained.

In addition, should a new geotechnical investigation be undertaken and additional piezometers installed, these should be monitored on a regular basis to detect changes and trends.

10.4 Recommendations

Hatch recommends the following OMS actions:

- Convert the manually read water level gauge for Naramata Lake to an automatic gauge to better monitor changing water levels. (See Issue No. NL-13 in Table 13-1).
- The Routine Dam Inspection report format should be improved by incorporating aspects of the BC Dam Safety Office's Site Surveillance Form (included in Appendix C). (See Issue No. All-3 in Table 13-1).
- Install new instrumentation including piezometers and reinstate/install weirs downstream of the dam along the channels. 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. NL-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. NL-11 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 no 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. It is recommended that RDOS undertake a record search of all suitable information archives, i.e. BCMoE Dam Safety Branch in Victoria for additional document and improvements. 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.
1.8	The IDF is based on appropriate hydrological analyses	X						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						Low level outlet performs as expected. Reservoir is empty or near-empty in winter condition (N/A). The dam is capable of passing its Inflow Design Flood without overtopping. A seismic event is not expected to adversely affect the spillway channel and path; any distress can be readily fixed.
1.10	The dam has adequate freeboard for all applicable operating conditions (normal, winter, earthquake, flood)			X			NCm, NCi	Freeboard analysis including wind/wave effects for normal and IDF conditions has been analyzed as part of this DSR and is adequate. Dam access is provided via a gravel road that crosses the spillway intake. Debris (a log) was observed on the gravel road in the spillway approach, and the potential to incur a build up of silt, sand and gravel within the spillway approach channel from vehicle activity should be monitored so a loss of freeboard does not occur. This material should be removed to maintain the intake level to that of the spillway weir sill. 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 were 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. 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			NCm	Vegetation is growing in the spillway approach channel, including small brush between the log boom and the access road. There is concern regarding maintaining the spillway crest elevation as the access road passes over the spillway entrance channel. Spillway exit channel includes some placement of riprap that should be inspected for erosion after any significant spill event.

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-conformances	Comments
					Actual	Potential		
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.
1.14	Adequate filter and drainage facilities are provided to intercept and control the maximum anticipated seepage and to prevent internal erosion			X	An, Au		NCi	Significant issues related to piping and exit gradients exist at the downstream toe of the dam. This has led to a recent boil at the toe of the dam. Hatch, following EBA (2010) assessment, has evaluated the condition and has put forward recommendation for the improvement of foundation piping issue.
1.15	Hydraulic gradients in the dams, abutments, foundations and along embedded structures are sufficiently low to prevent piping and instability			X	An, Au		NCi	Noted above. The critical exit gradients and potentially piping are not acceptable at the toe of the dam. Little information exists of the piping issues for materials inside the dam.
1.16	Slopes of the embankments have adequate protection against erosion, seepage, traffic, frost and burrowing animals			X			NCm	Dam exhibits minor 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 for situations such as the toe material (sand) boil.
2	**Operation, Maintenance and Surveillance**							
2.1	Responsibilities and authorities are clearly delegated within the organization for all dam safety activities	X						Should include a table with positions and associated names describing roles and responsibilities. Added as part of this project.
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.	X						
a.	Flow control equipment are tested and are capable of operating as required.	X						Flow control equipment is routinely/seasonally operated which satisfies annual testing of mechanical components of the dam.
b.	Normal and standby power sources, as well as local and remote controls, are tested.		X					N/A
c.	Testing is on a defined schedule and test results are documented and reviewed.	X						Flow control equipment is routinely/seasonally operated which satisfies annual testing of mechanical components of the dam.
d.	Management of debris and ice is carried out to ensure operability of discharge facilities	X						Debris booms are present at all spill locations. They are cleaned as needed.
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						
d.	Reliable flood forecasting information	X						

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-conformances	Comments
					Actual	Potential		
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. However, debris and vegetation should be removed along the spillway intake channel leading to the spillway crest. More consistent and thorough record keeping recommended.
	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						
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	Limited instrumentation (one piezometer) is installed in the dam, which is infrequently read (weekly during inspection) so there is a limited baseline of data to compare performance against. Information on normal range of values is not included. Such data should be plotted against the reservoir level. Recommendations are provided to install additional piezometers and weirs.
b.	Analysis of changes in performance, deviation from expected performance or the development of hazardous conditions			X			NCs	Limited instrumentation (one piezometer) is installed in the dam, which is infrequently read so there is a limited baseline of data to compare performance against. Such data should be plotted against the reservoir level and reviewed regularly. The instrumentation monitoring shall include continuous records, plotting, and interpretation of piezometer data and seepage flow quantities against reservoir elevation.
c.	Reservoir operations are confirmed to be in compliance with dam safety requirements	X						
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						

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-conformances	Comments
					Actual	Potential		
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.
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	Frequency of reading and person responsible for reading is included, however procedures not provided in OMS manual.
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						

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-conformances	Comments
					Actual	Potential		
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).
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					
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
NL-1	Dam is currently classified as a Very High consequence facility (FLNROR, 2011).	2020 DSR	-	New	Maintain the Naramata Lake Dam as a Very High consequence facility. Recommend adopting a dual classification system, where the classification for spill capacity alone can be reduced to a High. The Inflow Design Flood would equate to a flood with annual exceedance probability 1/3 between the 1000-year flood and the PMF.	Low	N/A	0	
NL-2	Documented history of toe seepage at downstream toe of the dam (EBA, 2010), observed again during the 2020 inspection. A sand boil was noted at the downstream toe.	2010 DSR, 2020 DSR	NCi	Outstanding	Existing construction records and seepage observations, including recent observation of a sand boil, indicate that previous mitigation methods are potentially only partially effective. Design and construct a toe filter blanket and confining berm. Excavate toe material and extend the toe into the ground to intercept under-flows and release foundation pore water pressure.	High	Major Capital Works	$215,000.00	
NL-3	Insufficient as-built documents and geotechnical data to conduct a complete geotechnical assessment of the dam. The 2010 DSR recommended a search for historical information and commissioning of a topographic survey (EBA, 2010).	2010 DSR, 2020 DSR	NCi	Resolved/ Outstanding	A topographic survey was completed in 2012. There is limited site-specific geotechnical information. Conduct a geotechnical investigation program and testing similar to the work carried out at the Big Meadow Dam.	High	Major Capital Works	$82,000.00	
NL-4	Lack of information on the dam strength against seismic and post-seismic behavior.	2020 DSR	NCi, Pu	New	Conduct a geotechnical assessment of the Naramata Dam for seismic and post-seismic resistance.	High	Major Capital Works	$35,000.00	Design up to preliminary design level.
NL-5	Debris such as silt, sand and gravel, and vegetation accumulated in the spillway channel (EBA 2010). Dam access is provided via a gravel road that crosses the spillway intake. Debris (a log) was observed on this road, crossing the spillway intake. Vegetation/brush was growing in the spillway inlet channel. (Hatch, 2020).	2010 DSR, 2020 DSR	NCm	Outstanding	Short term: Ensure the spillway approach is regularly inspected and clear the spillway approach of debris and vegetation if any blockages are found so that a loss of freeboard does not occur. Any materials should be removed to maintain the spillway intake levels to that of the spillway weir sill. The road should be maintained at a level below the weir crest elevation, with additional armor considered to prevent erosion to the road.	High	Minor Improvements	0	Operational cost
			NCm	New	In the longer term, consideration should be given to replacing the road with a small bridge such as bailey style or acrow style steel bridge and extending the excavated channel underneath.	Medium	Minor Capital Works	$20,000	
NL-6	Analysis indicates that the existing dam is able to pass the IDF with an available freeboard of 1.22 m., which is greater than the minimum requirement of 1.0 m (EBA, 2010). Using updated survey data, the 2020 DSR analysis indicates that the existing dam is able to pass the IDF including wind and wave effects with an available freeboard of 0.28 m to the lowest portion of the dam, which meets CDA requirements.	2010 DSR, 2020 DSR	NCm	Outstanding	Restore dam crest to design/typical crest elevation.	Medium	Minor Capital Works	0	
NL-7	Piping risk assessment shows that the risk of piping failure is higher than the tolerable limits defined by the CDA Dam Safety Guidelines. This was also noted in the 2010 DSR (EBA, 2010)	2010 DSR 2020 DSR	An	Outstanding	Assessment shows that piping risk is greater than the tolerable threshold, particularly for piping risk through the foundation. This is supported by observations of boils downstream. The risk of piping through the foundation should be addressed by the construction Internal piping potential and stability should be analyzed part of future geotechnical investigation and assessment of a toe berm as noted above.	High	Minor Capital Works	$35,000.00	Design up to preliminary design level.
NL-9	No Operations, Maintenance and Surveillance (OMS) manual was prepared for the dam as of the previous Dam Safety Review	2010 DSR	N/A	Resolved	An OMS manual has been published since the previous review (RDOS, 2017). The contents of the OMS were reviewed and revised as part of the 2020 review.	Medium	N/A	0	Resolved
NL-10	Dam Safety Review schedule	2020 DSR	-	New	In accordance with the Very High consequence classification, the next Dam Safety Review should be conducted in 2030, and every 10 years subsequently.	Medium	N/A	0	

Issue No.	Deficiency/Non-Conformance	Originator	Type	Status	Recommendation	Priority Rating	Cost Estimate - Type	Estimated Cost	Notes
NL-11	No information is available for the rate of drawdown and the procedures that should be used to accommodate lowering the reservoir for emergency drawdown.	2020 DSR	NCo	New	It is recommended to determine a better understanding of the rate of drawdown that can be achieved for emergency drawdown scenarios such as with the sand boil. A plan to utilize a portable syphon or one or more high volume pumps to provide capacity and emergency drawdown would be a cost effective way to providing required drawdown capacity. This should be evaluated for operations planning as well as potential sources for emergency pumps if needed. Under the CDA guidelines, it is recommended to provide information on staffing requirements and the time required to complete system operations. Add syphon Standard Operating Procedure (SOP) to OMS Manual.	Medium	Minor Capital Works	$50,000.00	Calculations would be small cost. Syphon itself could be less than the $50,000 presented.
NL-12	Lack of sufficient instrumentation for performance monitoring.	2020 DSR	NCi,s	New	Install new instrumentation including piezometers and reinstate/install weirs downstream of the dam along the channels. 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.	High	Minor Capital Works	$8,000.00	Cost for 2 weirs (Piezometer installation cost covered in ES-5)
NL-13	Lack of sufficient instrumentation for performance monitoring.	2020 DSR	NCi,s	New	It is recommended that an automatic water level gauge be installed on Naramata Lake, calibrated and regularly maintained to better monitor changing water levels.	Medium	Minor Capital Works	$10,000.00	
NL-14	OMS could be improved by providing additional information on procedures regarding instrumentation. This will assist Dam Safety inspectors in detecting and responding to an emergency situation.	2020 DSR	NCs	New	Procedures regarding instrumentation (piezometer) readings and data processing should be added to the OMS. This includes where 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. Plot piezometer locations plan and report flows. Pipe flows should be measured by bucket filling and documented.	Medium	Minor Improvements	0	
NL-15	Vegetation control along the tailrace channels	2020 DSR	NCs	New	Increase frequency of vegetation clearing along the tailrace trenches for future seepage/piping monitoring.	High	Minor Improvements	0	operational cost
NL-16	Currently no rip-rap 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.		Minor Capital Works		
NL-17	LLO structure is unprotected from vandalism and accidental damage from ATVs or other traffic at dam crest.	2020 DSR	NCm	New	Provide protection to the screw stem by adding bollards or a steel cover to prevent damage from ATV traffic.	Low	Minor Capital Works	$ 10,000.00	
NL-18	Recommendations recently provided to increase public safety and reduce risk to RDOS.	2019 Risk Survey, 2020 DSR	NCp	Outstanding	Review security protocols and implement appropriate restrictions including those set out in the 2019 Risk Control Survey (Precise Services, 2019) to prevent damage or vandalism.	High	Minor Improvements	$ 10,000.00	
NL-19	Minor concrete cracking in localized area around outlet pipe in LLO structure	2020 DSR	NCm	New	Repair the cracked area of concrete after chipping off the loose and cracked concrete section	Low	Minor Improvements	0	operational cost
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 aspect 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 "NL" (Naramata Lake) 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.

Golder Associates. Memo: "Re: Big Meadow Dam". 2 November 2004.

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

Kelowna Regional Office – Water Rights Branch. "Big Meadow Reservoir – Storage Capacity Table". 26 April 1979.

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

Kelowna Regional Office – Water Rights Branch. "Naramata Lake Reservoir – Storage Capacity Table". 29 June 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: "Big Meadow Lake Storage Dam". November 1952.

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: “Big Meadow Dam Site Topography”. 17 July 2012.

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. “Big Meadow Reservoir and Dam Operation, Maintenance and Surveillance Plan Emergency Preparedness Plan”. May 2017.

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 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.

Tannant, Dwayne D. and Skermer, Nigel. “Mud and debris flows and associated earth dam failures in the Okanagan region of British Columbia”. Canadian Geotechnical Journal. 13 June 2013. https://cdnsciencepub.com/doi/10.1139/cgj-2012-0206

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

Wilson, K.W. “Irrigating the Okanagan: 1860-1920.” M.A. thesis, The University of British Columbia. 1989. <https://open.library.ubc.ca/cIRcle/collections/ubctheses/831/items/1.0097929>

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

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

Appendix A
Site Visit Photo Report

Photo A1: Naramata Dam Upstream Crest, Looking from Left Abutment

Photo A2: Naramata Dam Crest, Looking at Left Abutment

Photo A3: Naramata Dam Upstream Slope, Looking from Right Abutment

Photo A4: Naramata Dam downstream slope, close to left abutment area

Photo A5: Naramata Dam downstream slope, close to left abutment area

Photo A6: Naramata Dam downstream tailrace channel

Photo A7: Naramata Dam Low Level Outlet structure, exit location and stilling basin

Photo A8: Naramata Dam tailrace channel weir

Photo A9: Naramata Dam, Spillway, looking at right abutment location along the crest

Photo A10: Naramata Dam spillway structure

Photo A11: Naramata Dam spillway downstream channel

Photo A12: Naramata Dam spillway downstream channel

Photo A13: Naramata Dam hoist structure

Photo A14: Naramata Dam piezometer on downstream slope close to right abutment

Photo A15: Naramata Dam, boil on the left drainage tailrace channel looking downstream

Photo A16: Boil at drainage tailrace channel

Photo A17: Naramata Dam left abutment

Photo A18: Naramata Dam Bent Intake Gate Stem

Photo A19: Naramata Dam Minor Concrete Damage in Outlet Structure

Appendix B
Seismic Hazard Characterization

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

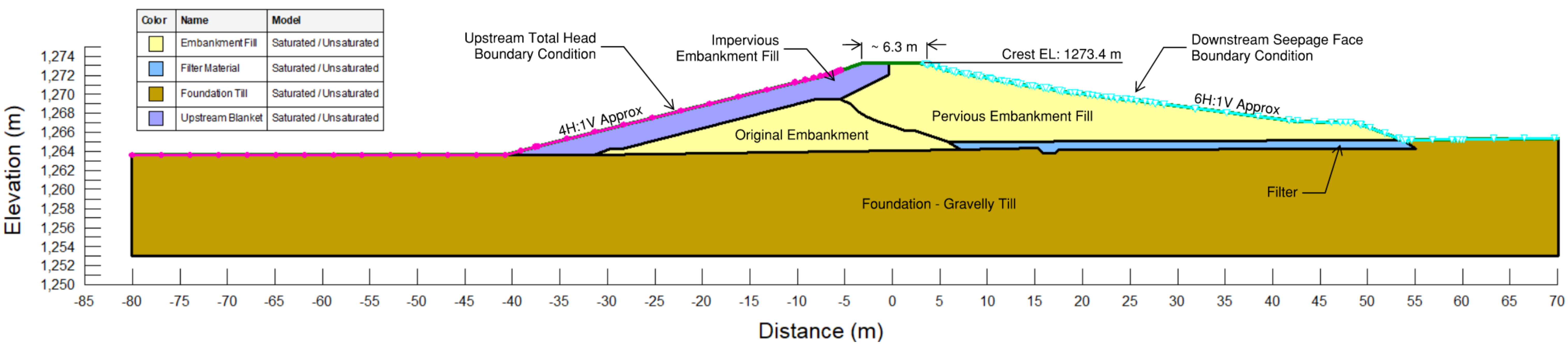
National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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

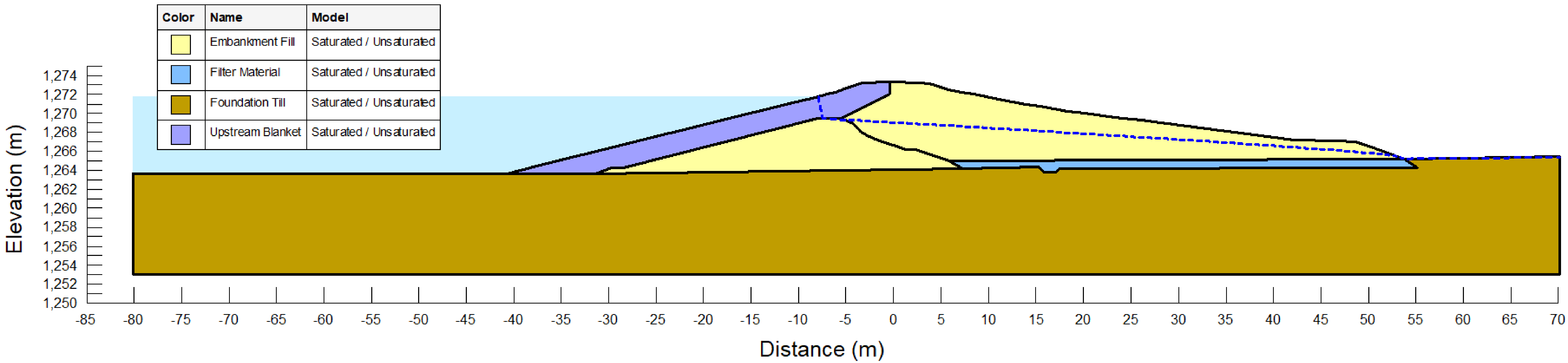
See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

Appendix C
Seepage Analysis Results



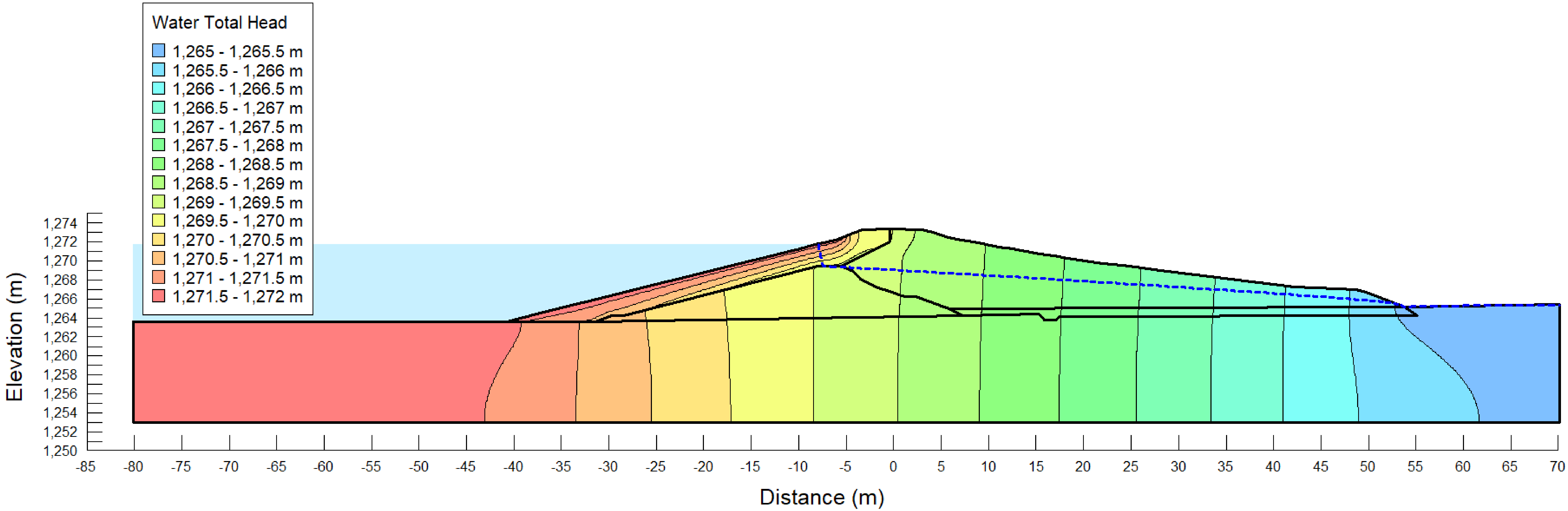
HATCH

Project	**Naramata Lake Dam – Dam Safety Review**		
Analysis Description	**Seepage Analysis: Model Geometry**		
Analysis By: T Singh	Scale: As Shown	Output	Model Geometry
Date	08/01/2021	Report No.	H3XXX



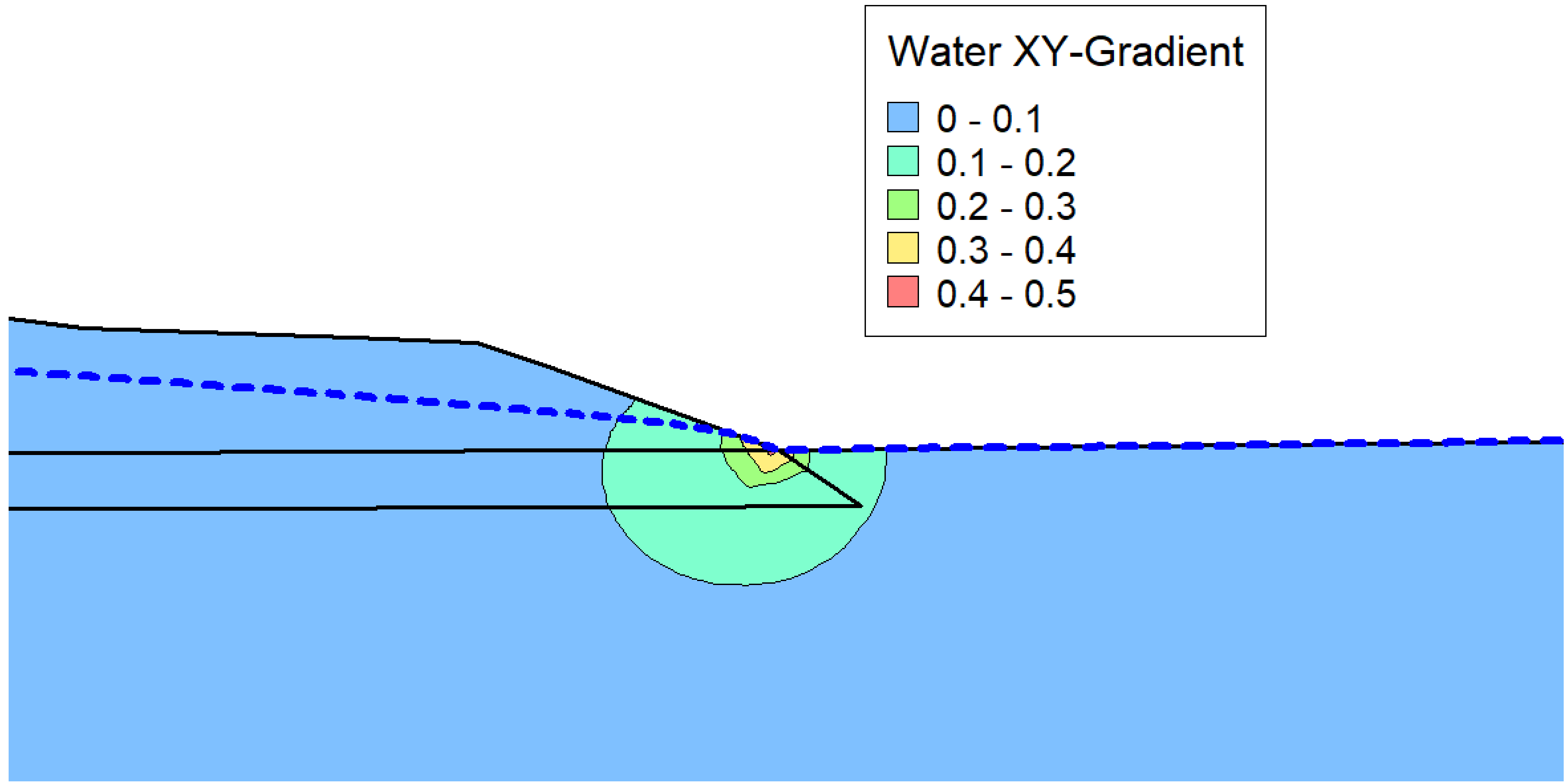
HATCH

Project	**Naramata Lake Dam – Dam Safety Review**		
Analysis Description	**Seepage Analysis: Steady State Condition – Full Supply Level**		
Analysis By T Singh	Scale As Shown	Output	Steady State Phreatic Surface
Date 08/01/2021		Report No.	H3XXX



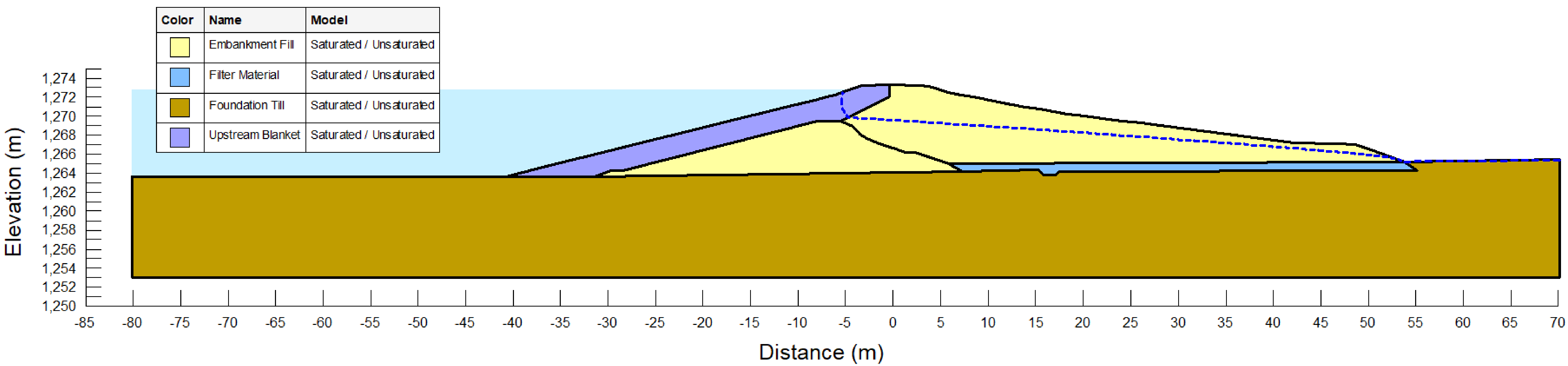
HATCH

Project	Naramata Lake Dam – Dam Safety Review		
Analysis Description	Seepage Analysis: Steady State Condition – Full Supply Level		
Analysis By: T Singh	Scale: As Shown	Output	Water Total Head (m)
Date	08/01/2021	Report No.	H3XXX

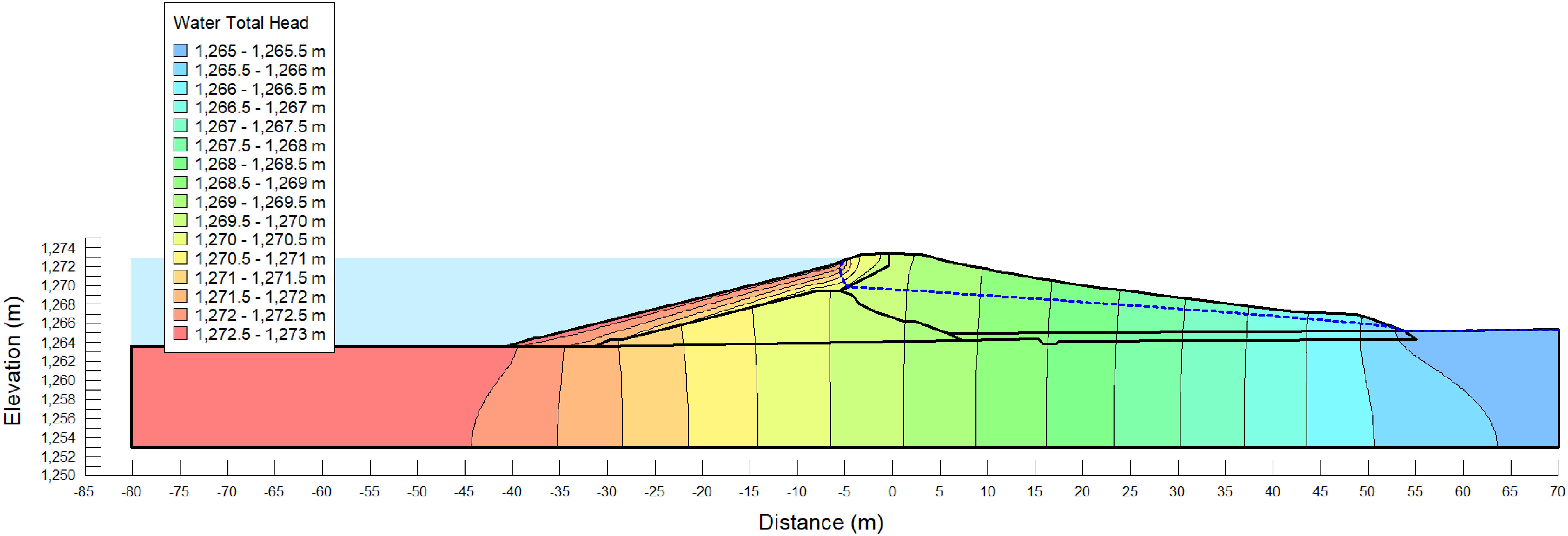


HATCH

Project	Naramata Lake Dam – Dam Safety Review		
Analysis Description	Seepage Analysis: Steady State Condition – Full Supply Level		
Analysis By T Singh	Scale As Shown	Output	Toe Exit Gradients
Date	08/01/2021	Report No.	H3XXX

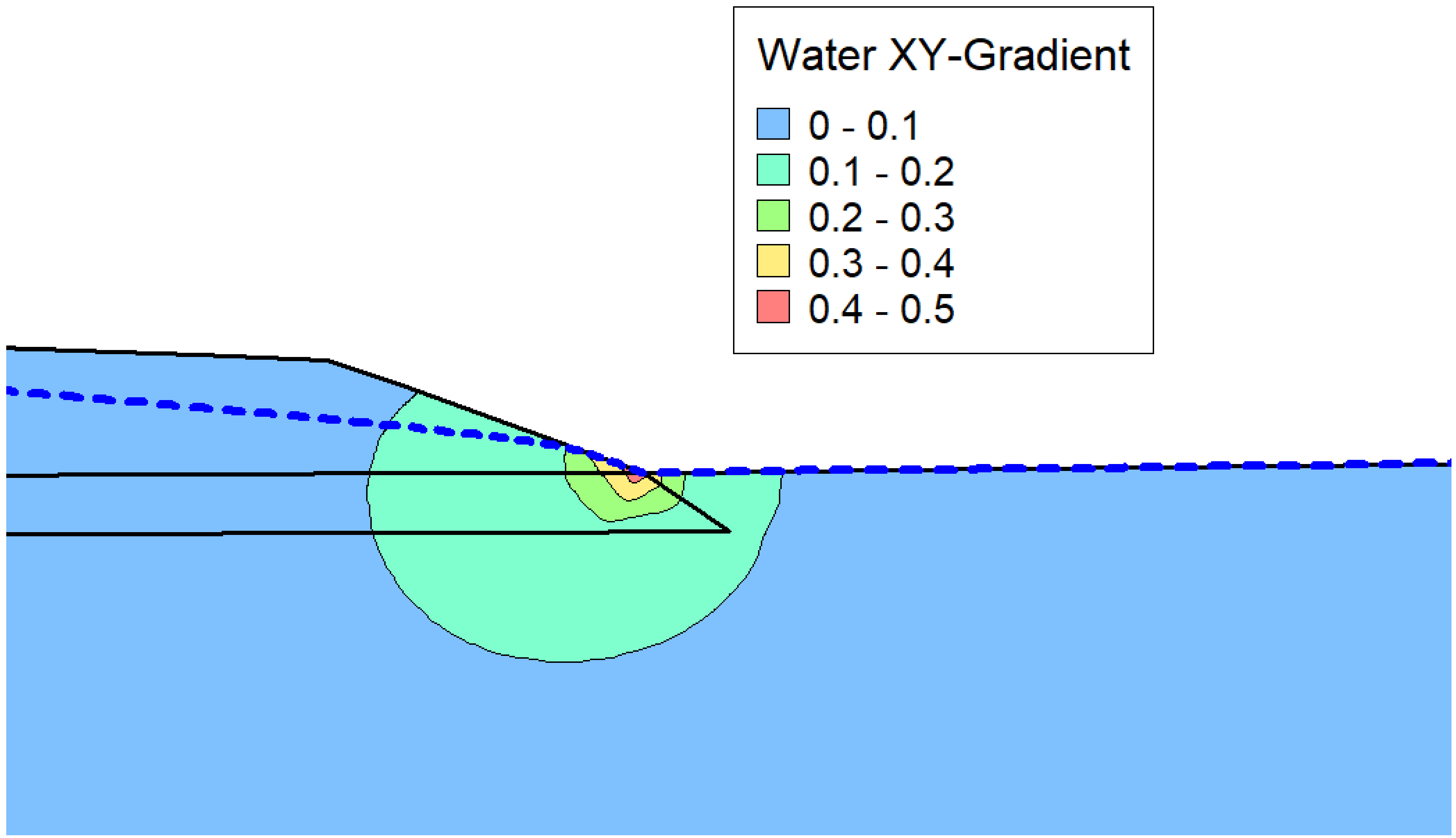


Project	**Naramata Lake Dam – Dam Safety Review**		
Analysis Description	**Seepage Analysis: Steady State Condition – Inflow Design Flood**		
Analysis By T Singh	Scale As Shown	Output	Steady State Phreatic Surface
Date 08/01/2021		Report No.	H3XXX

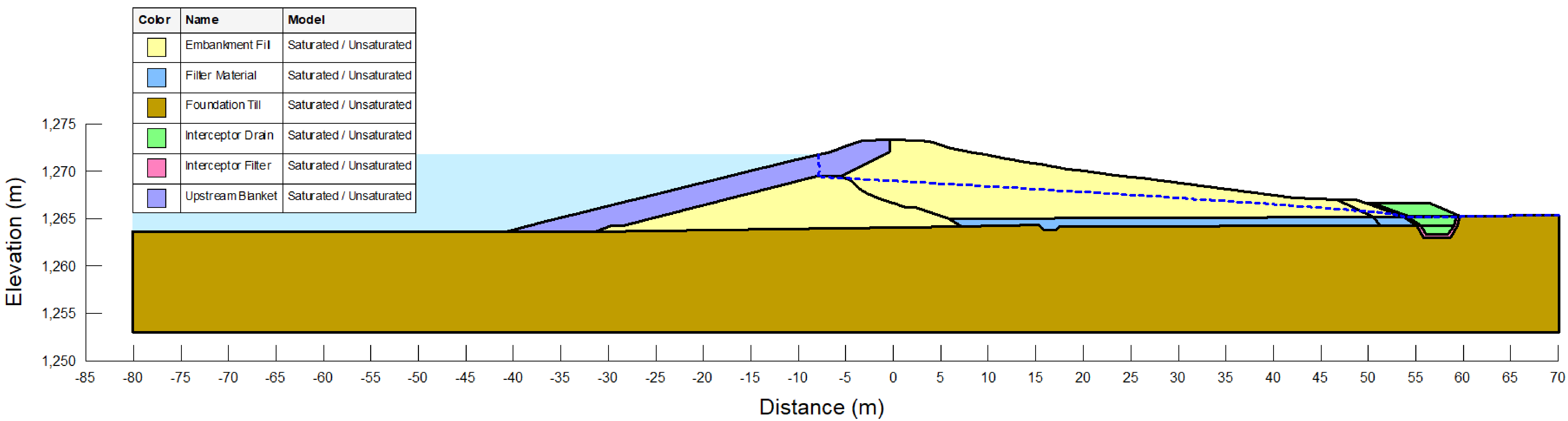


HATCH

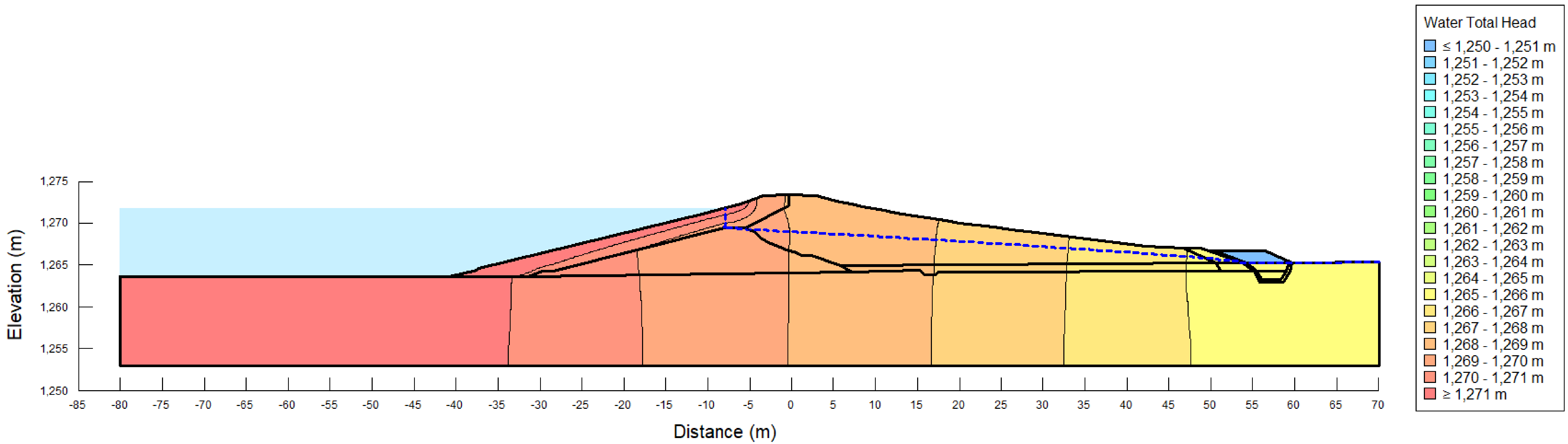
Project	Naramata Lake Dam – Dam Safety Review		
Analysis Description	Seepage Analysis: Steady State Condition – Inflow Design Flood		
Analysis By: T Singh	Scale: As Shown	Output	Water Total Head (m)
Date	08/01/2021	Report No.	H3XXX



HATCH	Project	Naramata Lake Dam – Dam Safety Review		
	Analysis Description	Seepage Analysis: Steady State Condition – Inflow Design Flood		
	Analysis By T Singh	Scale As Shown	Output	Toe Exit Gradients
	Date 08/01/2021		Report No.	H3XXX

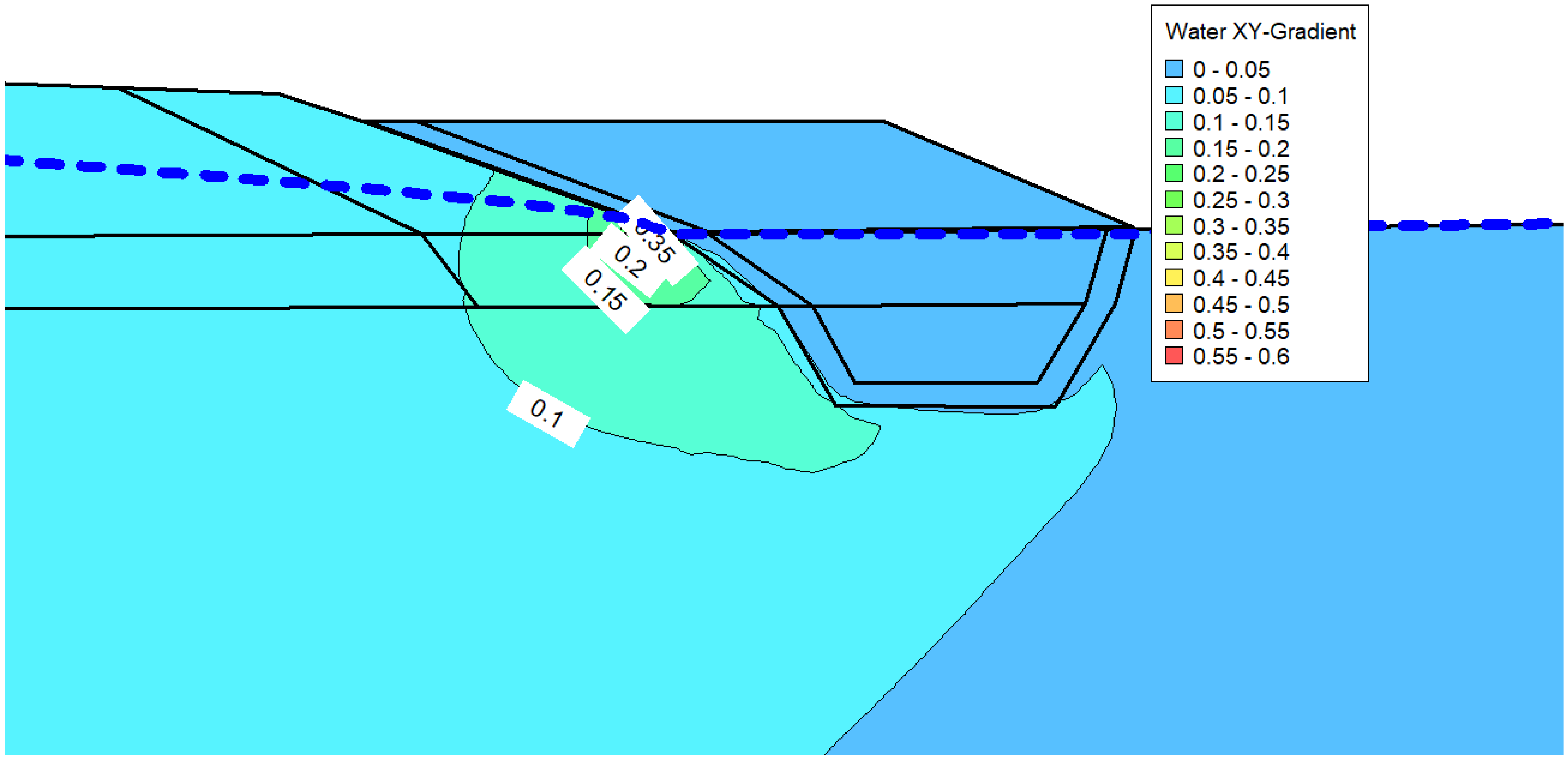


HATCH	Project	Naramata Lake Dam – Dam Safety Review	
	Analysis Description	Seepage Analysis: Steady State Condition – Full Supply Level – With Downstream Berm and Drain	
	Analysis By: T Singh	Scale: As Shown	Output: Steady State Phreatic Surface
	Date: 08/01/2021		Report No.: H3XXX



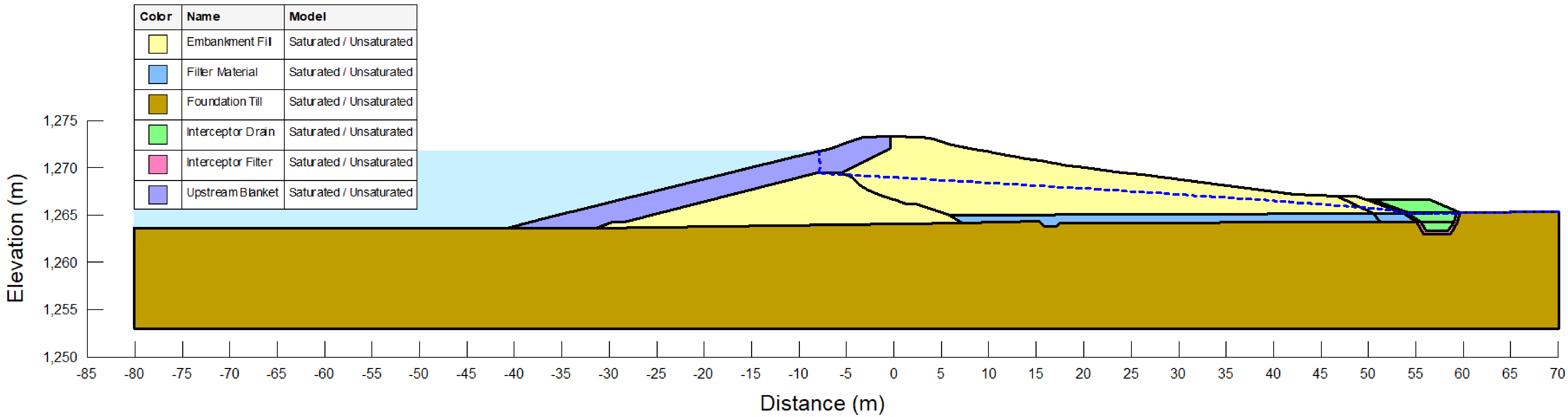
HATCH

Project	Naramata Lake Dam – Dam Safety Review		
Analysis Description	Seepage Analysis: Steady State Condition – Full Supply Level – With Downstream Berm and Drain		
Analysis By: T Singh	Scale: As Shown	Output	Water Total Head (m)
Date	08/01/2021	Report No.	H3XXX



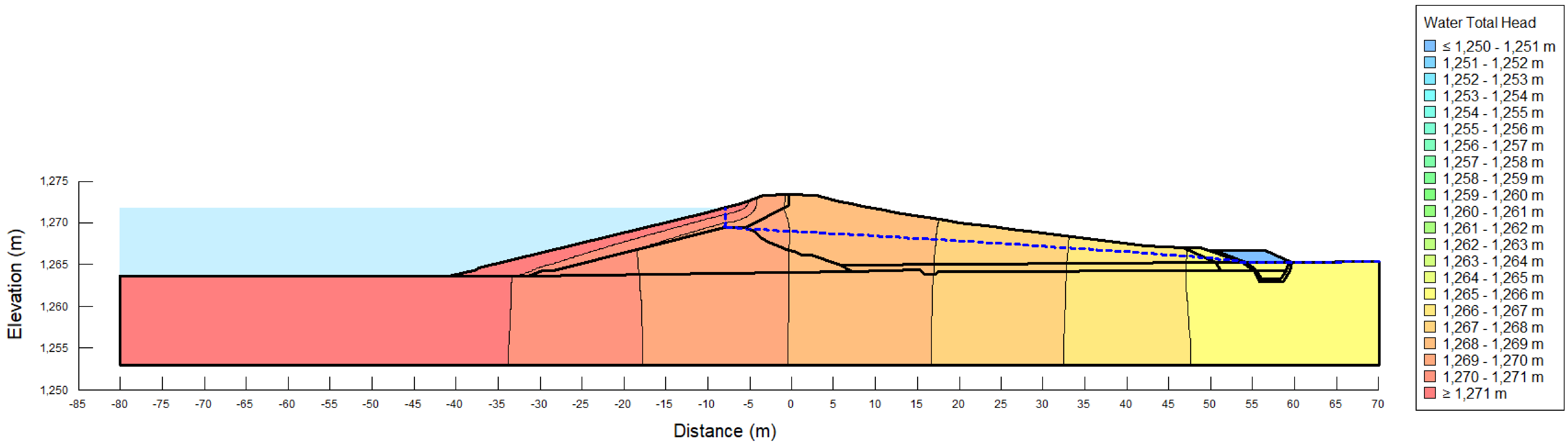
HATCH

Project	**Naramata Lake Dam – Dam Safety Review**		
Analysis Description	**Seepage Analysis: Steady State Condition – Full Supply Level – With Downstream Berm and Drain**		
Analysis By: T Singh	Scale: As Shown	Output	Toe Exit Gradients
Date	08/01/2021	Report No.	H3XXX



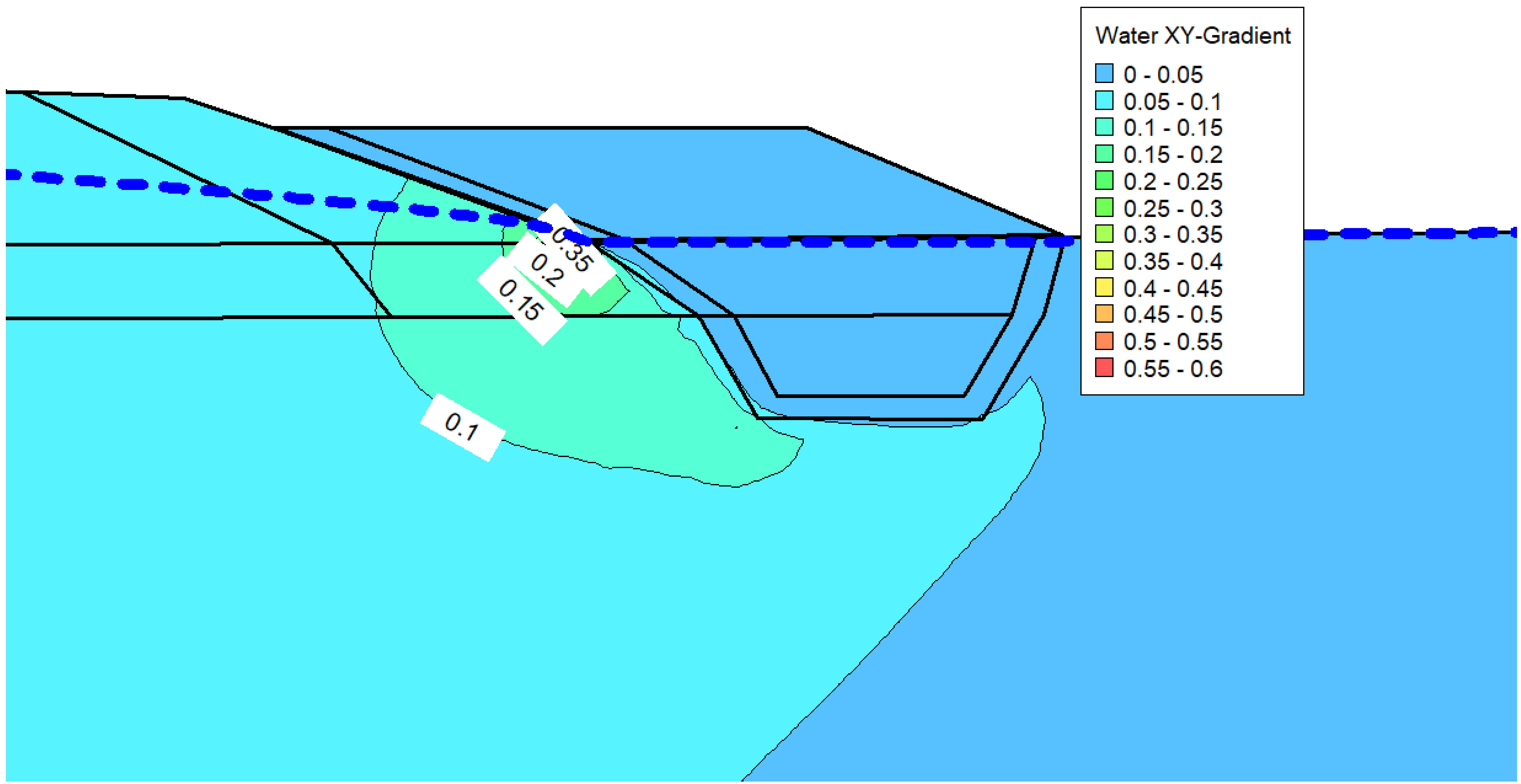
HATCH

Project	Naramata Lake Dam – Dam Safety Review		
Analysis Description	Seepage Analysis: Steady State Condition – Inflow Design Flood – With Downstream Berm and Drain		
Analysis By T Singh	Scale As Shown	Output	Steady State Phreatic Surface
Date	08/01/2021	Report No.	H3XXX

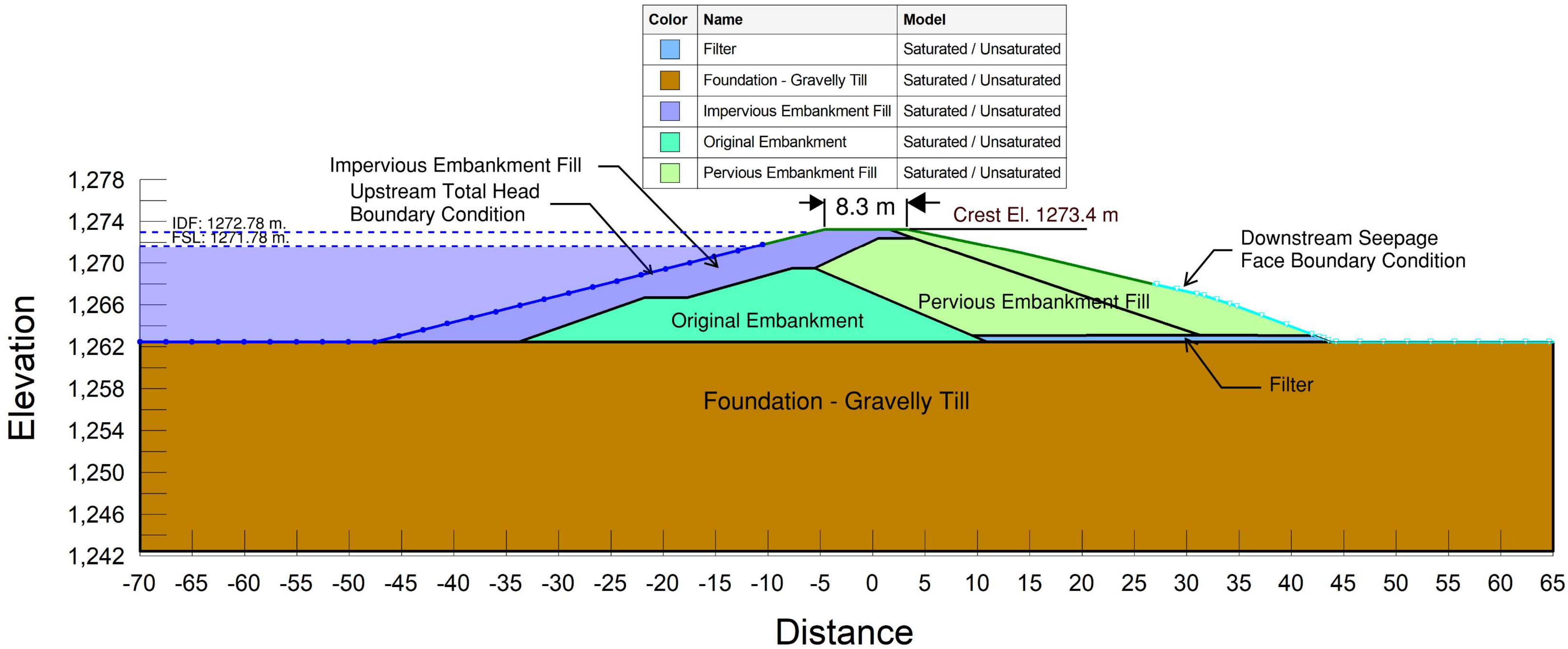


HATCH

Project	**Naramata Lake Dam – Dam Safety Review**		
Analysis Description	**Seepage Analysis: Steady State Condition – Inflow Design Flood – With Downstream Berm and Drain**		
Analysis By: T Singh	Scale: As Shown	Output	Water Total Head (m)
Date	08/01/2021	Report No.	H3XXX

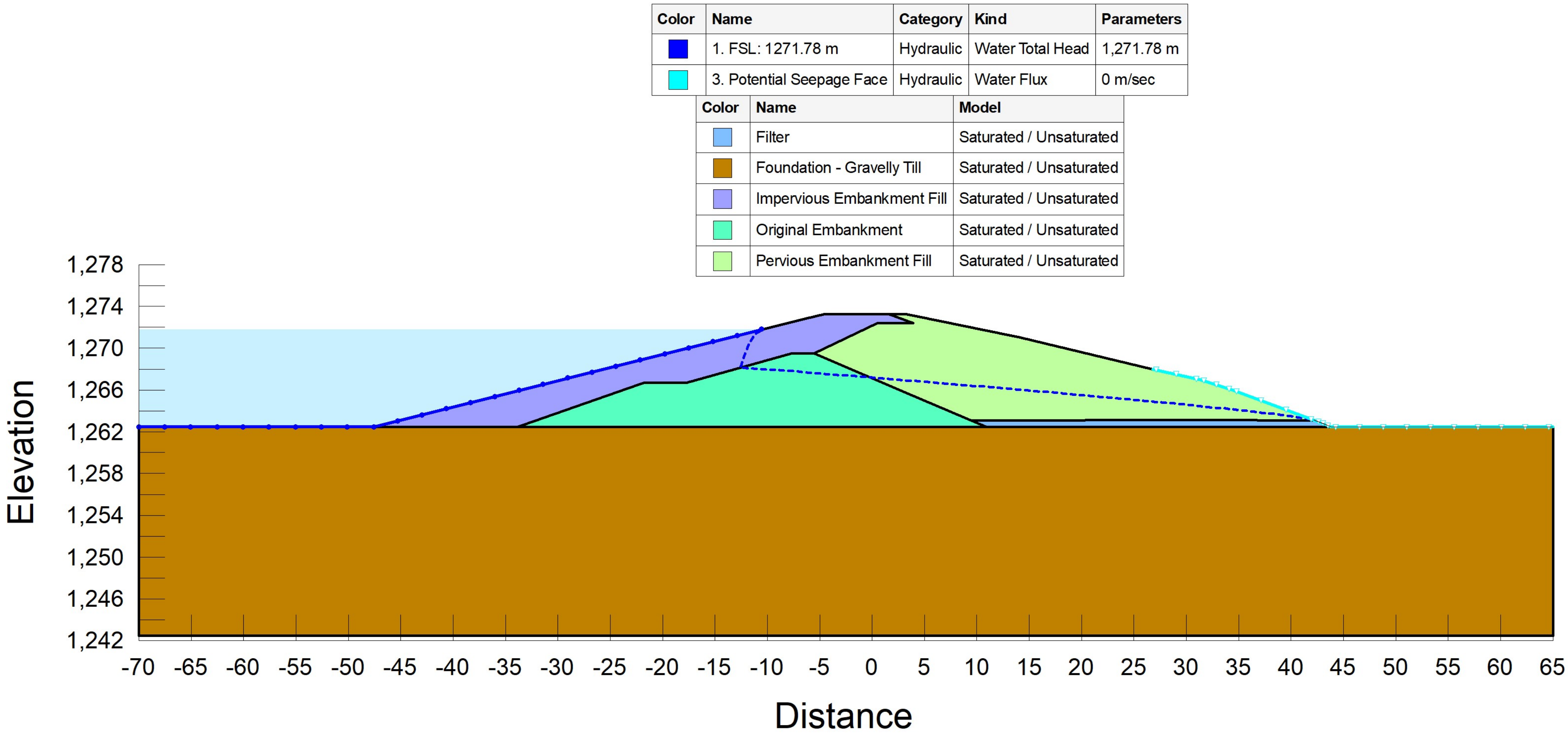


HATCH	Project	Naramata Lake Dam – Dam Safety Review		
	Analysis Description	Seepage Analysis: Steady State Condition – Inflow Design Flood – With Downstream Berm and Drain		
	Analysis By: T Singh	Scale: As Shown	Output	Toe Exit Gradients
	Date: 08/01/2021		Report No.	H3XXX



HATCH

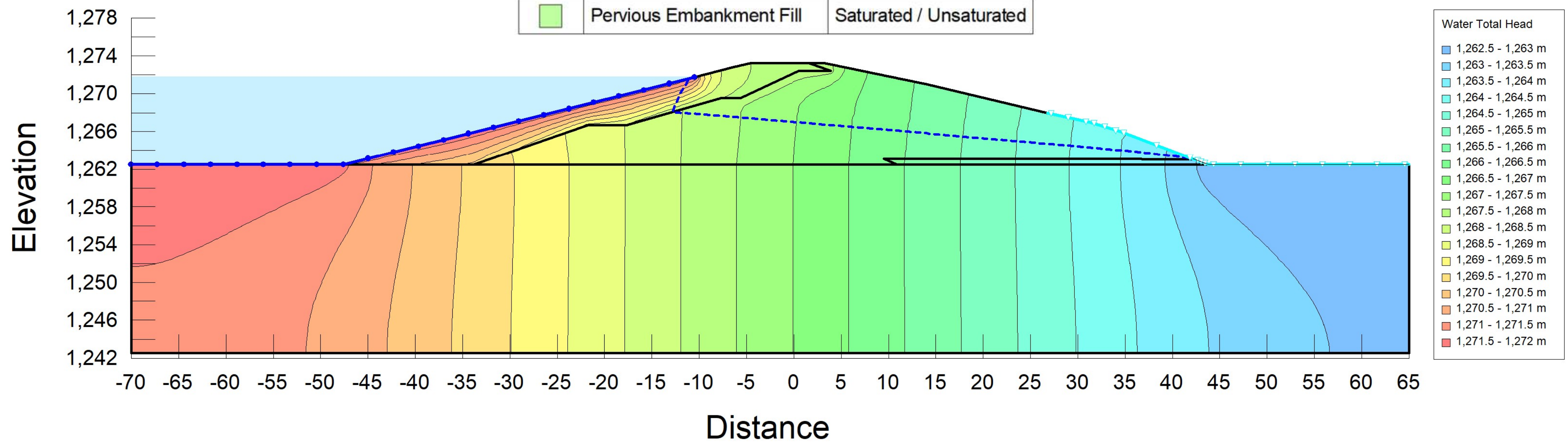
Project	**Naramata Lake Dam STA 0+240 – Dam Safety Review**		
Analysis Description	**Seepage Analysis – Model Geometry**		
Analysis By T. Tuo		Output	Model Geometry
Date 11/01/2021		Report No.	H362819



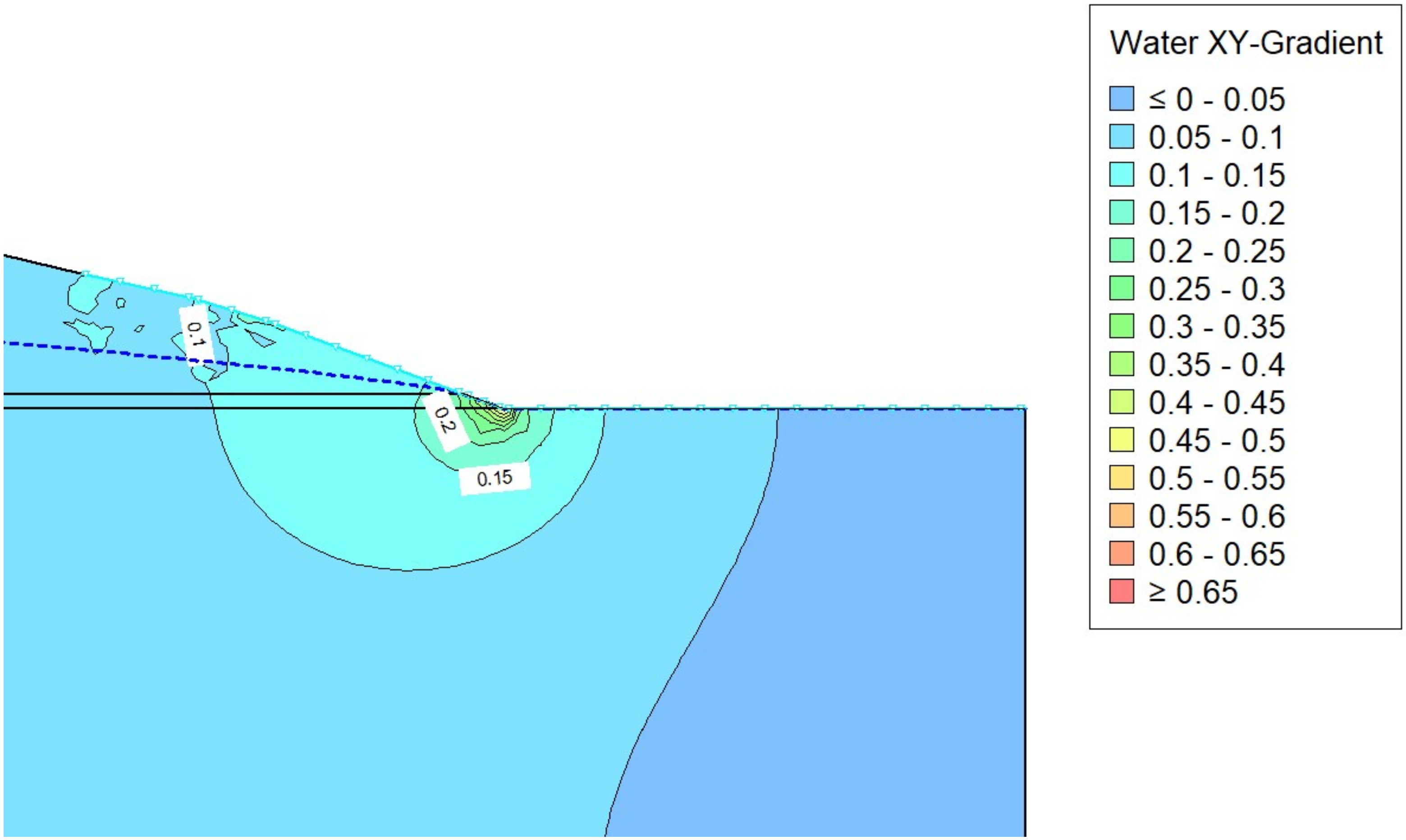
HATCH				
Project	Naramata Lake Dam STA 0+240 – Dam Safety Review			
Analysis Description	Seepage Analysis: Steady State Condition – Full Supply Level			
Analysis By	T. Tuo		Output	Steady State Phreatic Surface
Date	11/01/2021		Report No.	H362819

Color	Name	Category	Kind	Parameters
(blue)	1. FSL: 1271.78 m	Hydraulic	Water Total Head	1,271.78 m
(cyan)	3. Potential Seepage Face	Hydraulic	Water Flux	0 m/sec

Color	Name	Model
(light blue)	Filter	Saturated / Unsaturated
(brown)	Foundation - Gravelly Till	Saturated / Unsaturated
(lavender)	Impervious Embankment Fill	Saturated / Unsaturated
(green)	Original Embankment	Saturated / Unsaturated
(light green)	Pervious Embankment Fill	Saturated / Unsaturated



HATCH				
Project	**Naramata Lake Dam STA 0+240 – 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

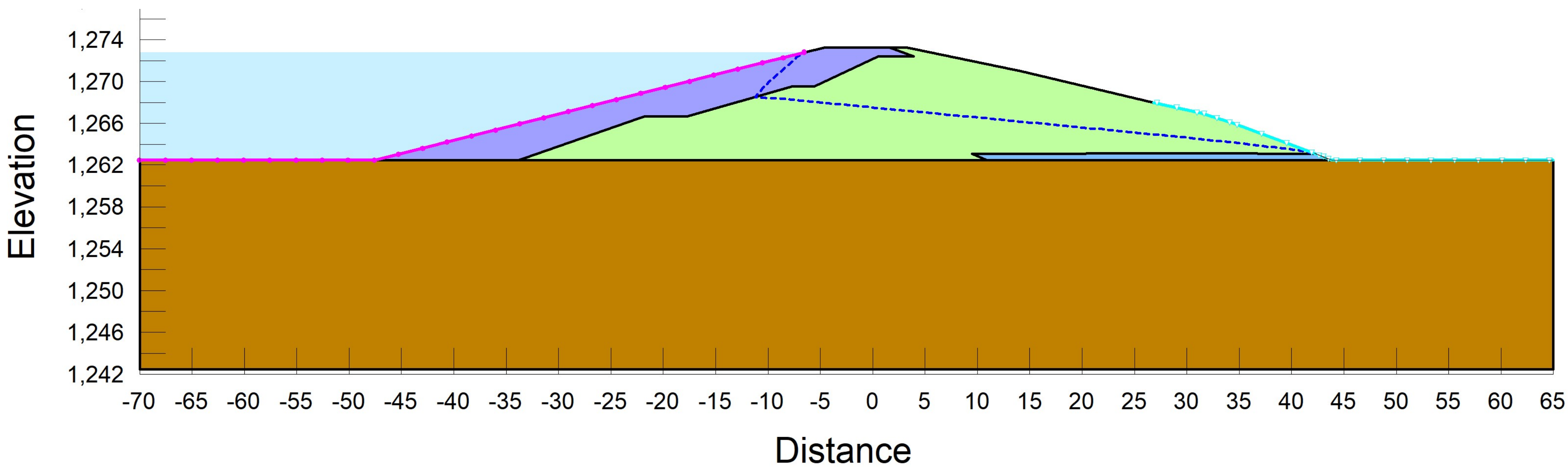


HATCH

Project	Naramata Lake Dam STA 0+240 – 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

Color	Name	Category	Kind	Parameters
	1.IDF: 1272.78 m	Hydraulic	Water Total Head	1,272.78 m
	3. Potential Seepage Face	Hydraulic	Water Flux	0 m/sec

Color	Name	Model
	Filter	Saturated / Unsaturated
	Foundation - Gravelly Till	Saturated / Unsaturated
	Impervious Embankment Fill	Saturated / Unsaturated
	Pervious Embankment Fill	Saturated / Unsaturated

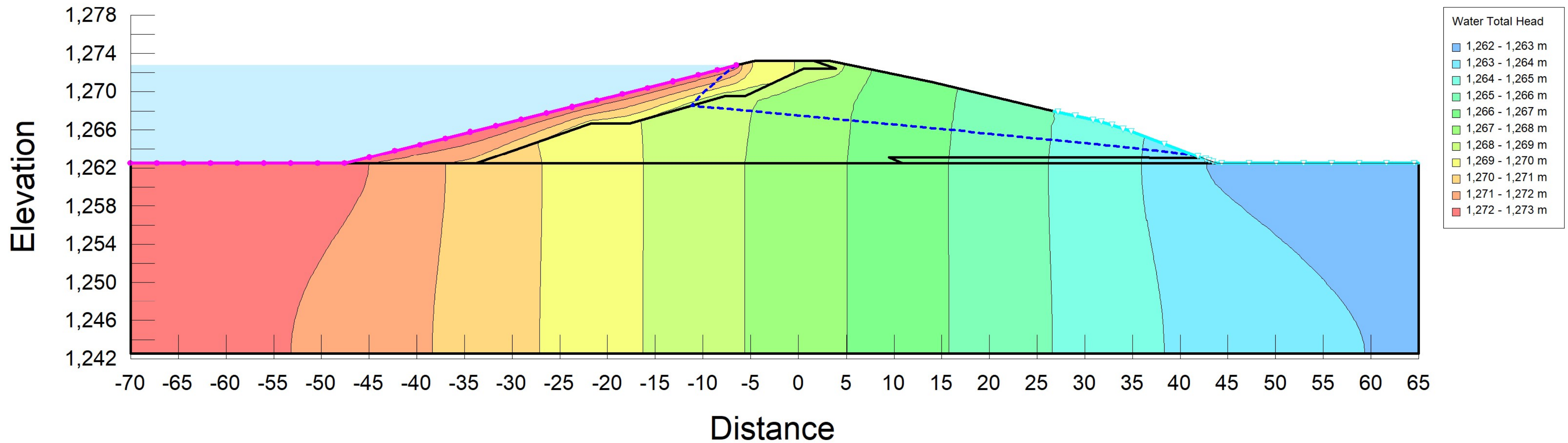


HATCH

Project	Naramata Lake Dam STA 0+240 – Dam Safety Review
Analysis Description	Seepage Analysis: Steady State Condition – Inflow Design Flood
Analysis By	T. Tuo
Output	Steady State Phreatic Surface
Date	11/01/2021
Report No.	H362819

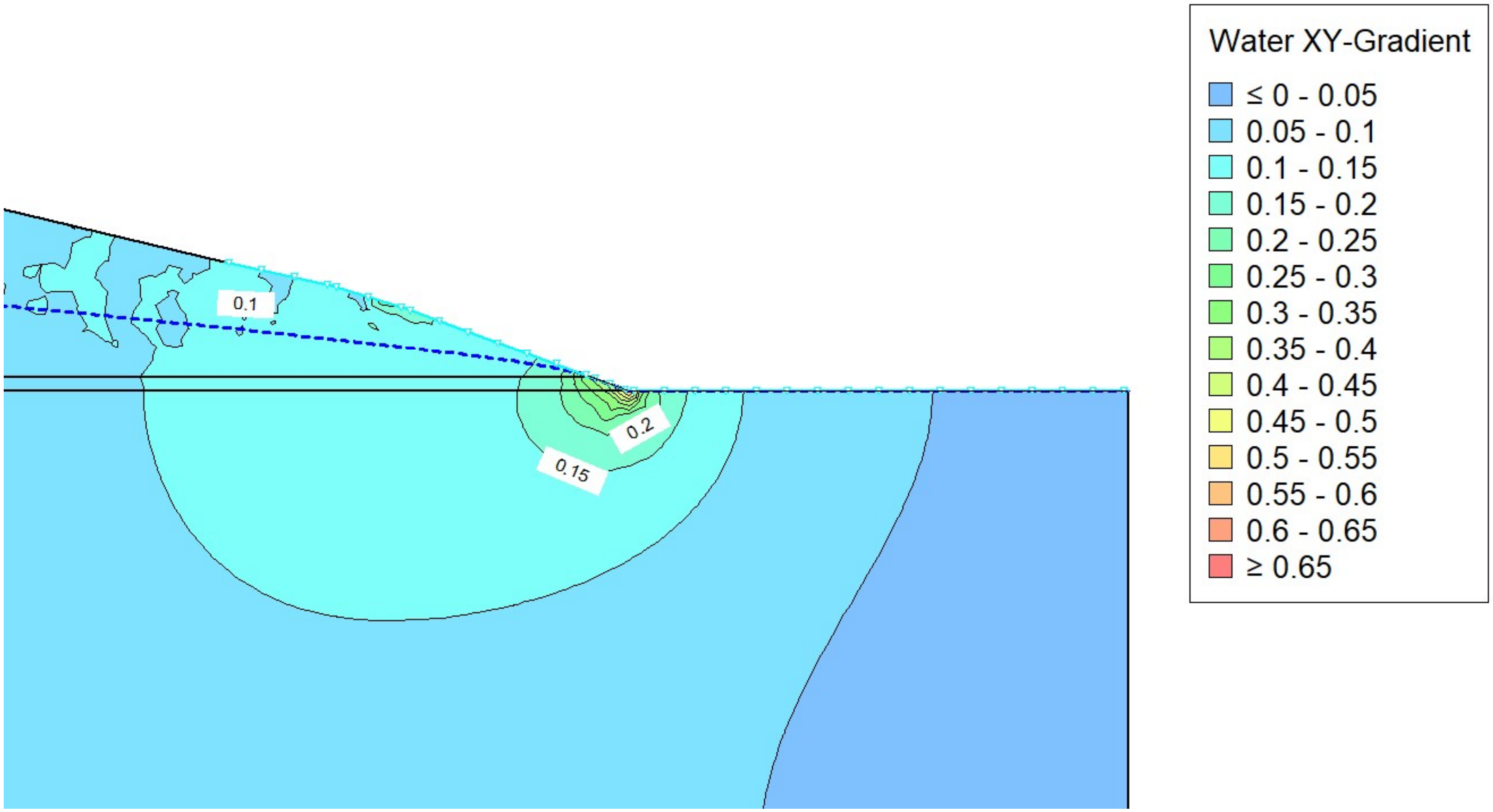
Color	Name	Category	Kind	Parameters
	1.IDF: 1272.78 m	Hydraulic	Water Total Head	1,272.78 m
	3. Potential Seepage Face	Hydraulic	Water Flux	0 m/sec

Color	Name	Model
	Filter	Saturated / Unsaturated
	Foundation - Gravelly Till	Saturated / Unsaturated
	Impervious Embankment Fill	Saturated / Unsaturated
	Pervious Embankment Fill	Saturated / Unsaturated



HATCH

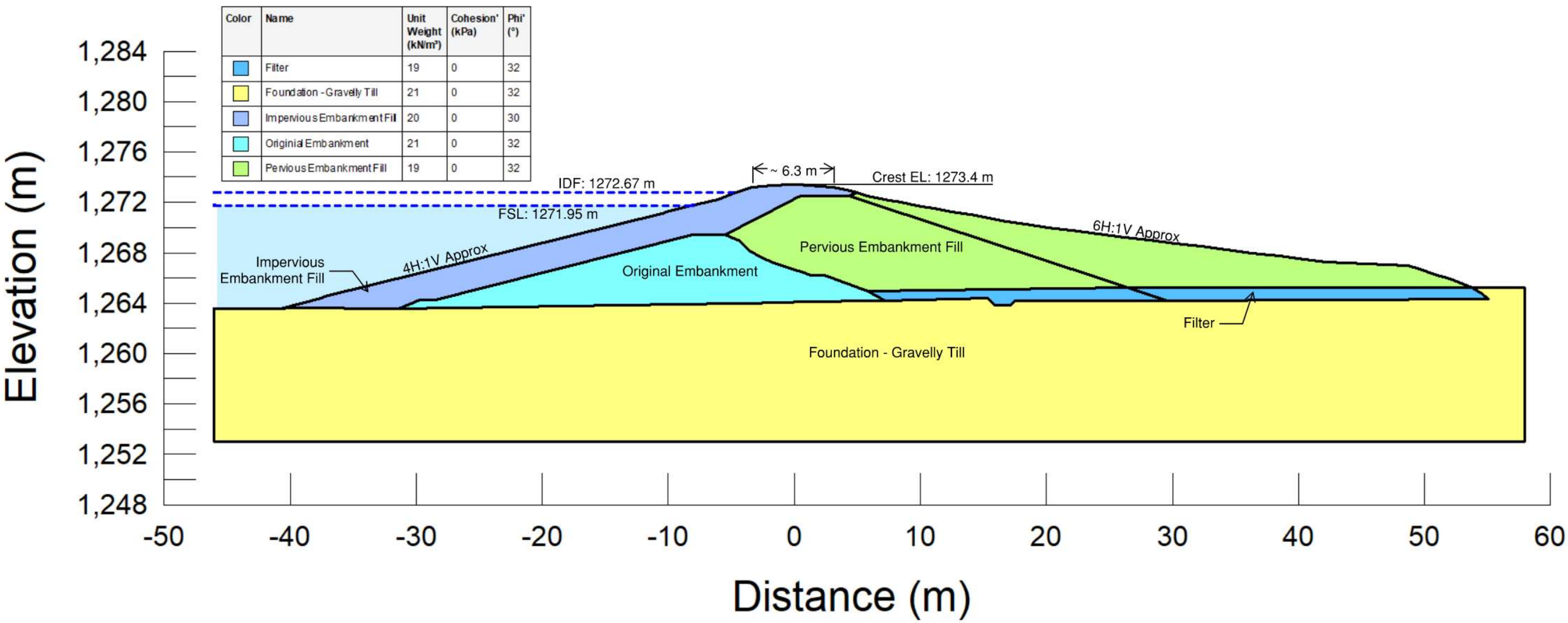
Project	Naramata Lake Dam STA 0+240 – Dam Safety Review		
Analysis Description	Seepage Analysis: Steady State Condition – Inflow Design Flood		
Analysis By	T. Tuo	Output	Water Total Head (m)
Date	11/01/2021	Report No.	H362819



HATCH

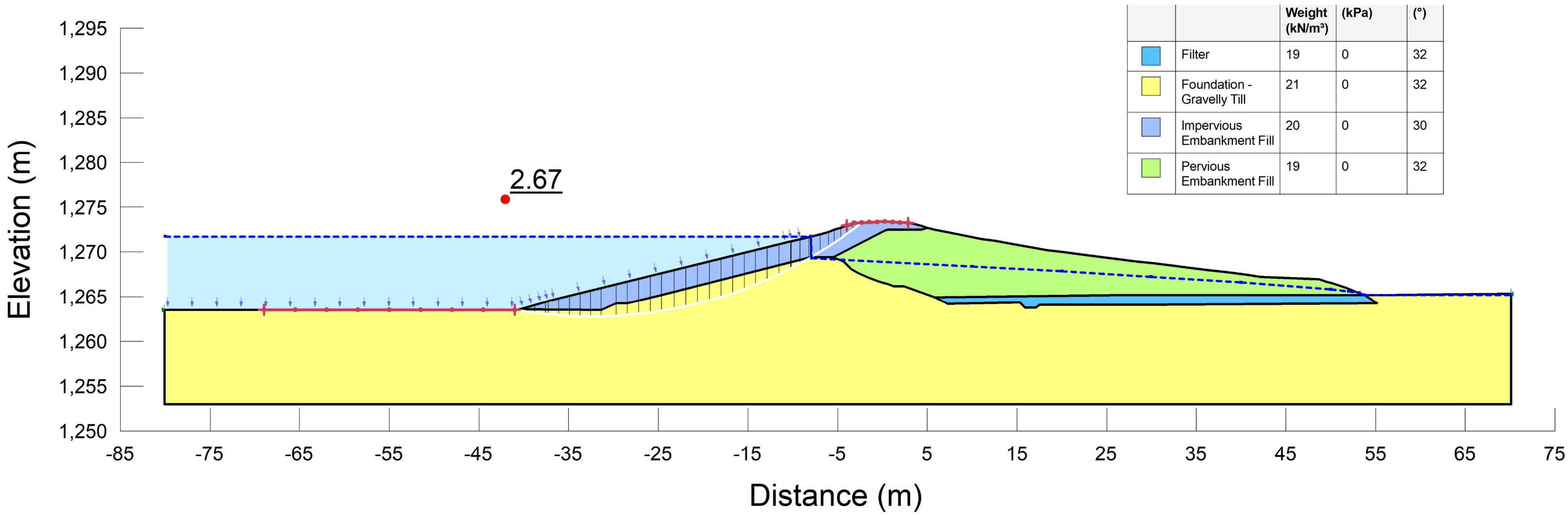
Project	**Naramata Lake Dam STA 0+240 – Dam Safety Review**		
Analysis Description	**Seepage Analysis: Steady State Condition – Inflow Design Flood**		
Analysis By	T. Tuo	Output	Toe Exit Gradients
Date	11/01/2021	Report No.	H362819

Appendix D
Slope Stability Analysis Results



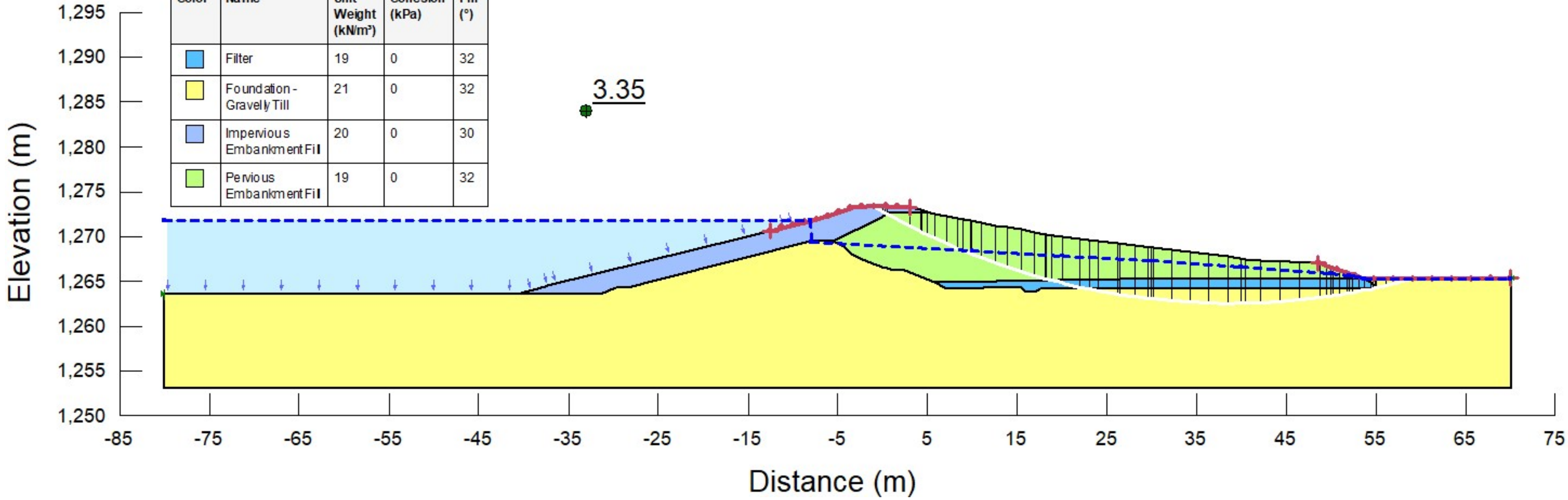
HATCH

Project	**Naramata Lake Dam – Dam Safety Review**		
Analysis Description	**Slope Stability Analysis: LC-1 – Normal Load Condition – Full Supply Level**		
Analysis By	T Singh	Slope	Upstream
Date	08/01/2021	Report No.	H362819



HATCH

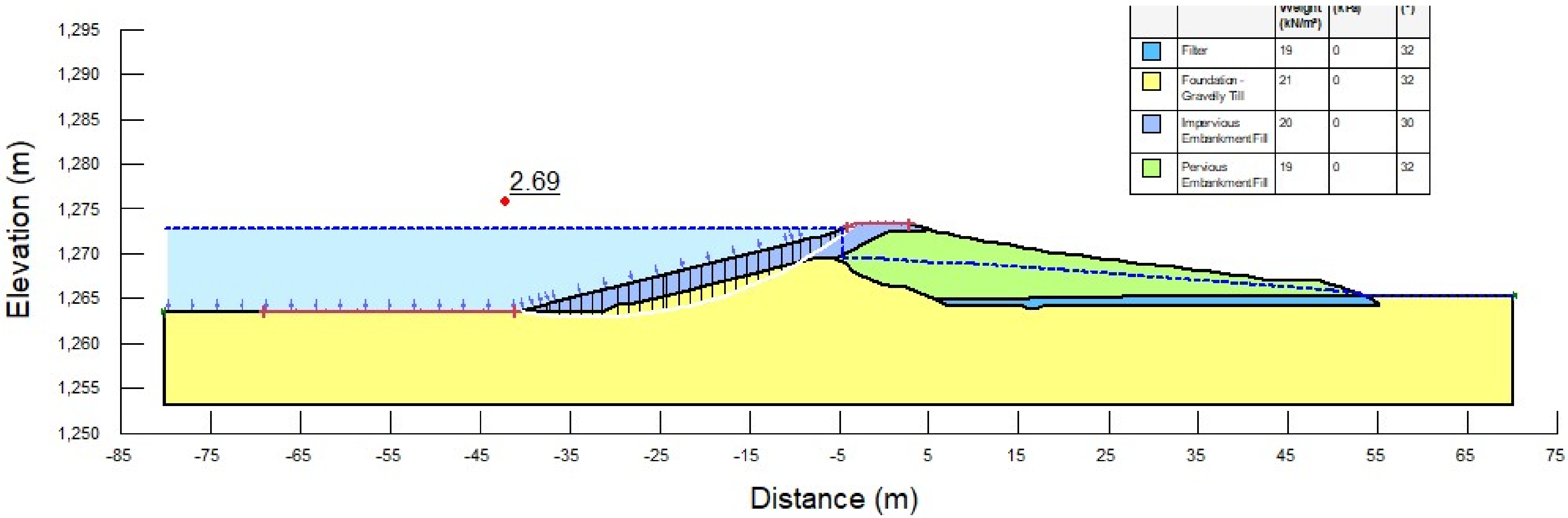
Project	**Naramata Lake Dam – Dam Safety Review**
Analysis Description	**Slope Stability Analysis: LC-1 – Normal Load Condition – Full Supply Level**
Analysis By: T Singh	Slope: Upstream
Date: 08/01/2021	Report No.: H362819



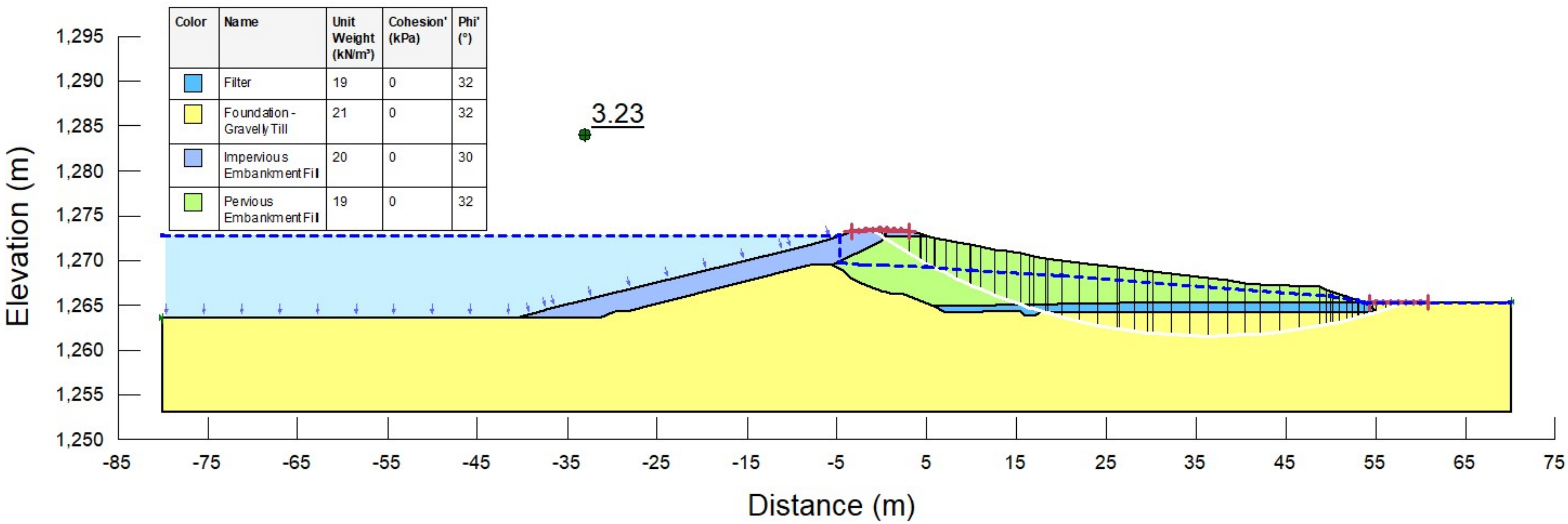
Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Filter	19	0	32
	Foundation - Gravelly Till	21	0	32
	Impervious Embankment Fill	20	0	30
	Pervious Embankment Fill	19	0	32

HATCH

Project	**Naramata Lake Dam – Dam Safety Review**
Analysis Description	**Slope Stability Analysis: LC-1 – Normal Load Condition – Full Supply Level**
Analysis By: T Singh	Slope: Downstream
Date: 08/01/2021	Report No.: H362819

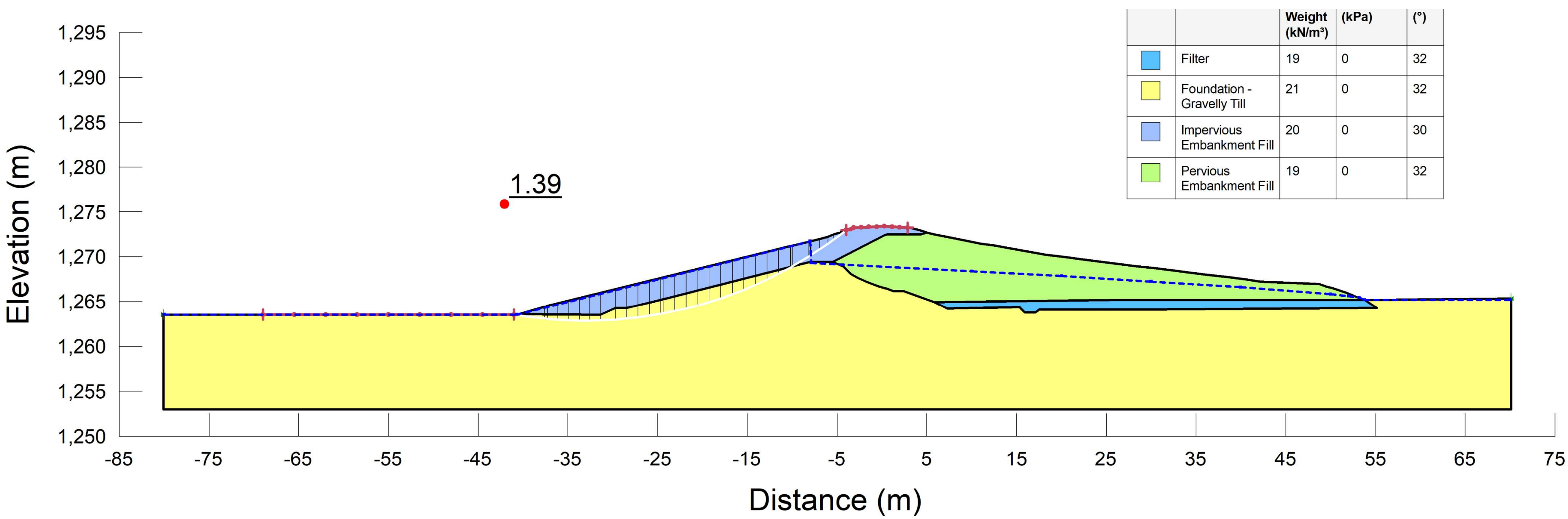


HATCH	Project	Naramata Lake Dam – Dam Safety Review		
	Analysis Description	Slope Stability Analysis: LC-2 – Flood Load Condition – Inflow Design Flood		
	Analysis By	T Singh	Slope	Upstream
	Date	08/01/2021	Report No.	H362819

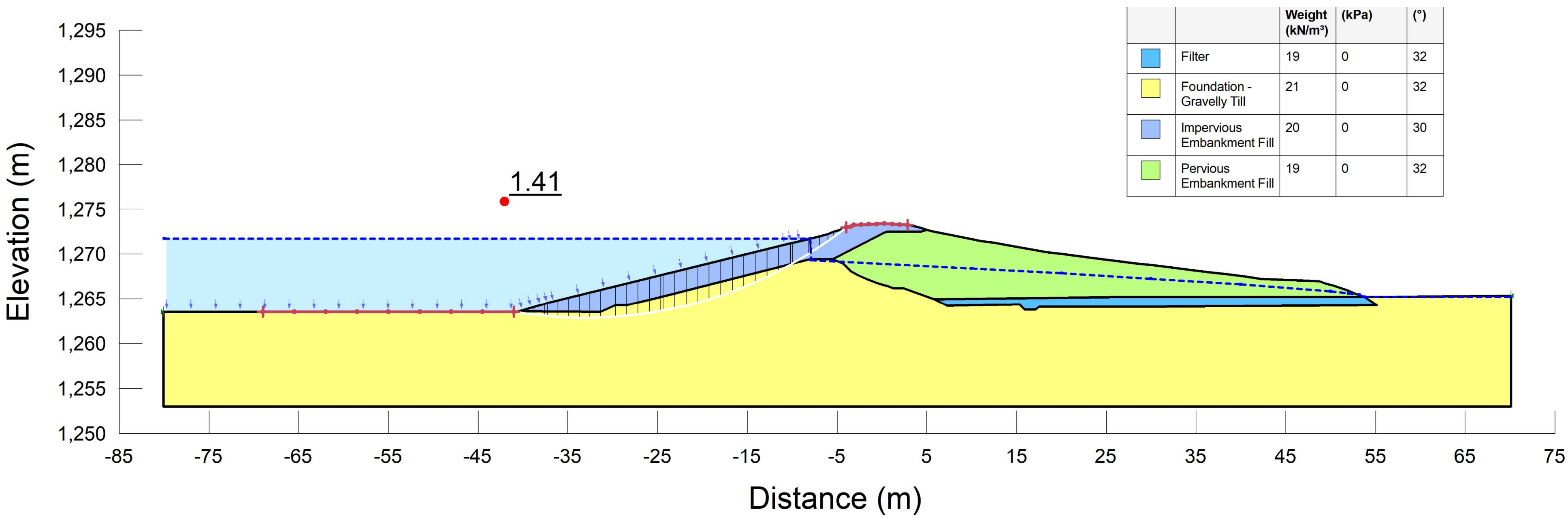


HATCH

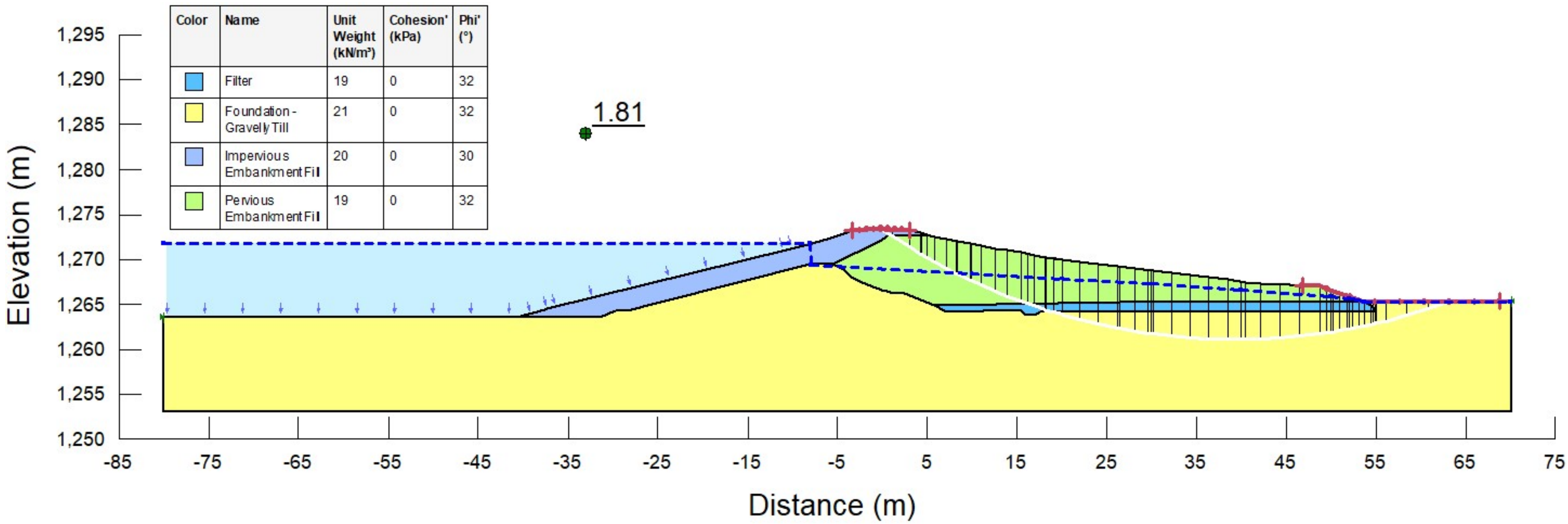
Project	Naramata Lake Dam – Dam Safety Review		
Analysis Description	Slope Stability Analysis: LC-2 – Flood Load Condition – Inflow Design Flood		
Analysis By	T Singh	Slope	Downstream
Date	08/01/2021	Report No.	H362819



HATCH	Project	Naramata Lake 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	08/01/2021	Report No.	H362819



HATCH	Project	Naramata Lake Dam – Dam Safety Review		
	Analysis Description	Slope Stability Analysis: LC-4 – Seismic Condition – Full Supply Level		
	Analysis By T Singh		Slope	Upstream
	Date 08/01/2021		Report No.	H362819



HATCH			
Project	**Naramata Lake Dam – Dam Safety Review**		
Analysis Description	**Slope Stability Analysis: LC-4 – Seismic Condition – Full Supply Level**		
Analysis By: T Singh		Slope	Downstream
Date: 08/01/2021		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):	Naramata Dam:49.6530 North, 119.5360 West
Located at (Description):	North to south trending valley, approximately 7.5 km to the northeast of the Naramata Township.
Name of dam or description:	Naramata Dam
Provincial dam number:	Naramata 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: ______________________ (signed)

Shayla Murphy ______________________

P. Ashayer ______________________

(signed) ______________________

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

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

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

PROFESSIONAL · PROVINCE OF BRITISH COLUMBIA · ENGINEER
P. ASHAYER
43014
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)