# 2023 Formal Annual Dam Inspections – Water Supply Dams

# Final Report

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## Disclaimer

This report has been prepared by Hatch for the sole and exclusive use of the City of Nanaimo (the “Client”) for the purpose of assisting the management of the Client in making decisions with respect to the management of the ten City-owned water supply dams (Jump Creek Dam and South Fork Dam) and shall not be (a) used for any other purpose, or (b) provided to, relied upon or used by any third party.

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(b) the report being read, with sections or parts hereof read or relied upon in context.

(c) the conditions of the ten dams 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.

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# 1. Introduction

The City of Nanaimo (the "City") retained Hatch Ltd. ("Hatch") to conduct Formal Annual Dam Inspections (FADI) for 10 City dams as per the BC Dam Safety Regulations. This report summarizes the results of the 2023 FADIs for the water supply dams which were undertaken by Hatch on September 26, 2023.

The City's Water and Resources and Water Supply Operations staff are responsible for the management and maintenance of 10 dams. Jump Creek and South Fork dams are located approximately 27 km and 21 km southwest of the City, respectively and are part of the City's potable water supply system. See **Figure B1** in **Appendix B**.

The scope of the inspection work included:

- Review of background information, including as-built drawings, rehabilitation records/drawings, previous FADI and dam safety review (DSR) reports, operation, maintenance and surveillance (OMS) manuals, and any available instrumentation records.
- Meet with City Waterworks Dam Inspectors who perform the daily operation, maintenance and surveillance on the dams and discuss the various issues they have observed since the 2022 FADI.
- Visit the dam sites and undertake visual inspections of the dams and compile a photographic record.
- Review of dam safety management strategies including:
  - Failure consequence classification;
  - operation, maintenance and surveillance;
  - recommendations for dam safety improvements; and
  - review and update of the dam safety issues database assembled from previous FADI.

The 2 water supply dams inspected are listed below with acronyms to identify the dams and maintain consistency with previous FADI reports:

- JCR - Jump Creek Dam
- SFK - South Fork Dam

A list of the documentation reviewed is provided in **Appendix A**, figures are presented in **Appendix B**, photographs are included in **Appendix C**, and the Mobile Dam Inspection Database forms from September 2023 are included in **Appendix D**. The following sections of this report document the results of the FADI.

# 2. Regional Geology

The general geological conditions of the inspected dam sites are based on the review of geological mapping of Vancouver Island (Ministry of Environment BC). **Table 2-1** is a summary of the surficial and bedrock geology.

**Table 2-1: Summary of Regional Geology of the Inspected Dam Sites**

| Dam | Regional Surficial Geology | Regional Bedrock Geology |
|---|---|---|
| Jump Creek Dam | Glaciofluvial sand and gravel deposits related to outwash from previous glaciation; moraine deposits. Some bedrock outcrops with little to no overlying sediment. | Bedrock belonging to the Island Plutonic Site. Consists of Granodioritic intrusive rocks, feldspar porphyritic intrusive rocks. |
| South Fork Dam | Sediments generally thicker than 1 m overlying bedrock. May include pockets of colluvium or perched glaciofluvial sediments. May overlap with fluvial sediments consisting of sand and gravel. Some bedrock outcrops with little to no overlying sediment. | Bedrock belonging to Mesozoic Vancouver group which includes Daonella and Karmutsen formation. Consists of undivided sedimentary rocks, marine sedimentary volcanic rocks with lesser amounts of mudstone, Siltstone, and Basaltic Volcanic rocks. |

# 3. Dam Safety Program

## 3.1 Dam Failure Consequence Classification

The Dam Failure Consequence Classifications (DFCC) of the City's dams are determined in accordance with the B.C. Water Sustainability Act Dam Safety Regulation [B.C. Reg 44/2016]. The current classifications of the two water supply dams included in this FADI are summarized in **Table 3-1** below.

**Table 3-1: Dam Consequence Classification Ratings**

| Dam | Dam Failure Consequence Classification |
|---|---|
| Jump Creek | Very High |
| Jump Creek Auxiliary | High |
| South Fork Dam | Very High |

A dam breach assessment and inundation mapping project was completed for Jump Creek and South Fork Dams in September 2020, independent to the annual formal dam inspections. This assessment included a review of the DFCC for Jump Creek Main Dam and Auxiliary Dam and the South Fork Dam. The B.C. Dam Safety Regulation and CDA Guidelines present a classification system based upon the potential “incremental” losses that could be caused by a hypothetical dam breach, excluding the damages that would be caused

by a natural flood event of the same magnitude without a breach. Results for the incremental loss of life during the inflow design flood scenarios demonstrate that, many of the vulnerabilities are located within the low-lying regions of the floodplain and would be inundated by the natural flood alone, prior to the arrival of the dam breach flood wave. Incorporating expected additional time for evacuation during flood events lowers the incremental loss of life estimate further for IDF events, with hypothetical dam breach events occurring during normal or Sunny Day conditions governing each overall DFCC. The DFCC were unchanged for the Jump Creek and South Fork dams from the previous FADIs.

Recommendations for each dam are listed as follows:

### *3.1.1 Jump Creek Dam and Jump Creek Auxiliary*

The dam classification is currently 'Very High' for the Jump Creek Dam and 'High' for the Jump Creek Auxiliary. The dam classification is consistent in all three categories (loss of life, infrastructure and economic losses, and environmental and cultural losses) for both the Main Dam and Auxiliary Dam based on the 2020 DFCC study.

### *3.1.2 South Fork Dam*

The dam classification is currently 'Very High' for the South Fork Dam based on the recent 2020 DFCC+ study. It is of interest to note that it is not loss of life that governs the Very High DFCC. Loss of life alone would justify a High DFCC category, but the potential environmental and cultural losses bring the overall dam classification up to a Very High. For South Fork Dam, infrastructure and economic losses could be considered a Very High as well, if the City chooses to include the Water Supply as a third party.

## 3.2 Operating, Maintenance and Surveillance Manuals

The City has prepared Operating, Maintenance and Surveillance (OMS) manuals for each of their 10 dams. A high-level review of the manuals was performed as part of the FADI and appear to contain the relevant information that is expected in an OMS manual. Copies of the manuals are kept in the City of Nanaimo Public Works and City Engineering libraries. These copies have been distributed to key City personnel and are available electronically for the City Dam Inspectors to access during routine inspections if required. The manuals are updated periodically as required. The following updated documentation was provided as part of the 2023 FADI:

- Jump Creek Dam – OMS Manual (May 2022).
- Dam Inspection Database (updated records of weekly dam inspections).

Comments regarding the OMS manuals are listed below:

- The Jump Creek OMS manual should be updated to include a revision history.

## 3.3 Dam Emergency Plan

The City of Nanaimo has a comprehensive Dam Emergency Plan (DEP) which was last updated in 2019.

## 3.4 Dam Safety Management

The City of Nanaimo updated their Dam Safety Management Program document in July 2020. The most recent FADI recommendations should continue to be updated annually.

## 3.5 Surveillance

### *3.5.1 General*

As per previous FADIs, the City Waterworks Dam Inspectors take piezometer and seepage weir readings three times a week at Jump Creek and South Fork dams and perform inspections and record reservoir levels daily (Monday to Friday). Water levels are also available on a continual basis and are connected with the City's SCADA system. Water quality is tested weekly from the middle of June to the middle of September (weather dependent). It should be noted that the City was not able to maintain the usual inspection frequency during part of 2023 (including September and October) due to lack of available inspectors. Regular and diligent monitoring of instrumentation and visual inspection observations is integral as these are Very High consequence classification dams and are essential for the City's water supply.

Additional site surveillance occurs after storm events and earthquakes. A more comprehensive inspection is carried out monthly which includes taking instrumentation readings.

The inspectors are equipped with a heavy-duty laptop computer for outdoor use and the information collected during the weekly and monthly inspections is entered directly into the City's Mobile Dam Inspection Database. The most recent weekly and monthly checklists from the database were reviewed by Hatch and have been included in **Appendix D**.

The City of Nanaimo surveillance and instrumentation reading frequencies were compared against the BC Dam Safety Regulation. The monthly inspection frequency is appropriate for the Significant consequence classification dams as well as the weekly surveillance frequency for the High and Very High consequence classification dams.

### *3.5.2 Piezometers and Weirs*

As part of the routine inspections, the seepage elevation over the 'V' notch weirs are recorded by measuring the flow elevation above the base of the 'V' notch. This data is plotted on graphs to help identify trends. It is recommended that the seepage elevations be converted to flow to produce more informative plots that would track better with lake levels and rainfall records and significant changes will be more readily apparent.

Due to the low flow at the weirs, the drawdown is expected to be minimal and the seepage measurements at the weirs are effective at identifying trends.

## 3.6 Items from Previous FADI and DSR

The outstanding dam safety and maintenance issues/recommendations are updated annually in the FADIs. These items are listed in **Table 5-1** and **Table 5-2** of the report for outstanding Inspection and Surveillance and Dam Safety Issues, respectively.

# 4. Formal Annual Dam Inspections

Visual inspections of the dams were carried out by Mehdi Mehrbakhsh, P. Eng. (Structural Engineer) and Laura Paquet, P. Eng. (Geotechnical Engineer) from Hatch on September 26, 2023. The Hatch inspectors were accompanied by City of Nanaimo staff:

- Jaymie Miller – Lead Supervisor – Waterworks
- Euan Wilson – Water Resources Section

The daily inspection activities and weather conditions are summarized in **Table 4-1**.

**Table 4-1: FADI Activity Summary**

| Date (2023) | Weather | Summary of Inspection Activities |
|---|---|---|
| September 26 | Temperature: 22°C - 29°C<br>Conditions: Rainy (5-10 mm) and windy | 9:45 AM: Jump Creek Dam<br>1:00 PM: South Fork Dam |

It should be noted that heavy rain (> 20 mm) happened in the area in the days preceding the site inspections.

As part of the review, the main dam structures were inspected as well as the areas immediately upstream and downstream of the dams that were accessible or clearly visible from the dams. Observations from these inspections are documented for each dam in the sections which follow. For the purpose of this report, all location descriptions are oriented in a downstream facing direction. A photographic record of the inspections is included in **Appendix C**.

Prior to entering the dam sites, Hatch filled out field visit safety forms to identify potential hazards and City staff provided additional safety information as required for working in the watershed. The condition rating of the various components of the City's dam structures shown in this document will be consistent with the following:

- Satisfactory: Minimal wear or deterioration; like new condition. No repairs required.
- Fair: Normal material wear or deterioration. Functionally adequate for all intended uses.
- Poor: Abnormal material wear, deterioration, or local defects. Components may not fulfill intended uses. Major maintenance or repairs advisable to restore component to a satisfactory condition. If maintenance or repairs are not carried out, the design life of the component may be severely limited, and the component may become unsafe.
- Unsatisfactory: Severe material wear, deterioration, or local defects. Components will not fulfill intended uses. Immediate repair or replacement required. Present situation threatens the structural integrity of the project and represents an unsafe condition.

The major recommendations of this FADI are summarized at the end of this report in **Table 5-1** and **Table 5-2** and have been ranked using a priority rating system described in **Section 5**, which was established independent of the CDA Guidelines.

## 4.1 Jump Creek (JCR)

### *4.1.1 Dam Description*

Jump Creek Dam is located approximately 27 km southwest of Nanaimo on Jump Creek, a tributary to the South Nanaimo River (**Figure B1** in **Appendix B**). Jump Creek Dam was constructed in 1974 and consists of two zoned earth fill embankments founded on glacial till. The dam has undergone several modifications over the years, including the addition of spillway overshot gates in 1987, the addition of a steel liner in the upper transition section of the low-level outlet in 1988 (to prevent further cavitation damage), a new spillway entrance channel groin, new crest arrangements, a new emergency overflow spillway in the Saddle Dam in 2000, and low-level outlet modifications in 2002.

The main dam is 464 m long, 25 m high and is comprised of a central low permeability till core together with upstream and downstream sand and gravel shell zones. The upstream face slopes at 2.5H:1V (Horizontal: Vertical) and is protected with riprap. The downstream face also slopes at 2.5H:1V and is not protected with erosion protection measures.

The main service spillway is located near the right abutment of the main dam and includes two 2.4 m high by 7.5 m wide steel flap gates separated by a centre pier which supports an access bridge. The spillway has a discharge capacity of 189 $m^3/s$. The spillway chute descends the right-hand groin of the dam and terminates in a plunge pool (**Figure B2** in **Appendix B**). The spillway gates are operated on a regular basis with the gates being raised in the spring and lowered in the fall. The gates are also greased a couple times a year as part of regular maintenance. The main spillway bridge spans between the spillway piers and consists of a reinforced concrete slab (**Photograph JCR 4**). There are steel beams bearing on the concrete slab which are used to elevate the spillway bridge deck and provide clearance for the spillway gate gear drive and stem.

A new log boom was installed in July 2019 and is located 50 m upstream of the main spillway to provide protection to the spillway from debris originating in the reservoir. The log boom arrangement consists of one 20 ft-long log on each end of the boom to articulate the shoreline slope and fourteen 40 ft-long logs in the centre. The logs are a minimum of approximately 500 mm diameter and are connected together with chains. The boom is connected to anchor points on either side of the spillway. The left anchor is located on the main embankment slope approximately 60 m northwest of the spillway structure and consists of a 900 mm diameter corrugated steel pipe (CSP) infilled with concrete and a concrete anchor block partially submerged at the toe of the riprap (**Photograph JCR 3**). The right anchor is located in the forest on the right shoreline approximately 180 m to the southwest of the spillway structure. The anchor consists of a concrete anchor block covered with earth fill material and a new anchor consisting of four concrete lock blocks chained together. Both sets

of anchors were observed to be connected together with chains but the connection was not currently taut (**Photograph JCR 2**), which will result in loading (and ultimately the movement) of the old smaller concrete block prior to the new larger concrete lock blocks being engaged.

The low-level outlet within the main embankment consists of a reinforced concrete box culvert 1.37 m wide by 1.22 m high at the base of the dam, controlled by a 1.52 m by 1.52 m cast iron slide gate installed on the slope of the dam and operated by a gate stem controlled from a platform at the dam crest (**Photograph JCR 18**). A steel liner starts 99 m upstream of the outlet to the tunnel and extends approximately 7.5 m upstream. The energy from the flow through the LLO is dissipated at the downstream end by a standard USBR type impact stilling basin.

The Saddle Dam/Auxiliary Spillway (**Photographs JCR 40 to JCR45**) is approximately 154 m long and 6.7 m high and is an earth fill dam with central impervious core. Modular concrete lock blocks and a geomembrane form an additional freeboard for the central core of the dam. The auxiliary dam has a maximum discharge capacity of 45 $m^3/s$. The upstream face slopes at 2.5H:1V and the downstream face slopes at 2H:1V. Both slopes are protected with riprap (**Figure B3** in **Appendix B**).

The details of the Jump Creek Dam and Appurtenant structures are summarized in **Table 4-2**. The Jump Creek Saddle Dam/Auxiliary Spillway data are summarized in **Table 4-3**.

**Table 4-2: Data for Jump Creek Dam and Appurtenant Structures**

| Structure | Details |
|---|---|
| Type of Dam | Earth fill with central impervious core |
| Maximum Height | 25 m |
| Crest Length | 464 m |
| Crest Width | 6.1 m |
| Crest Elevation – Core Elevation | 381.0 m – 380.59 m |
| Upstream Slope | 2.5H:1V |
| Downstream Slope | 2.5H:1V |
| Retained Water (spillway gate down) | 13,300,000 $m^3$ |
| Retained Water (spillway gate up) | 16,600,000 $m^3$ |
| Low Level Outlet | Sluice gate 1.5 m x 1.5 m, invert level of opening 363.91 m, concrete outlet<br>1.2 m x 1.2 m, length 91.4 m<br>Trash rack 4.3 m x 3 m, opening size 300 mm |
| Spillway | Two overshot gates hinged at spillway crest, 7.5 m wide x 2.4 m high<br>Spillway crest elevation 376.43 m, maximum elevation 378.3 m, maximum discharge 189 $m^3/s$ at top of dam core |
| Hazard Rating | Very High |

**Table 4-3: Data for Jump Creek Saddle Dam/Auxiliary Spillway**

| Structure | Details |
|---|---|
| Type of Dam | Earth fill dam with concrete modular blocks |
| Maximum Height | 6.7 m |
| Crest Length | 154 m |
| Crest Width | 3 m |
| Crest Elevation | 380.74 m |
| Upstream Slope | 2.5H:1V |
| Downstream Slope | 2H:1V |
| Retained Water | See main dam |
| Auxiliary Spillway | Crest length 73 m; crest elevation 380.59 m; maximum discharge 45 $m^3/s$ |
| Hazard Rating | High |

### *4.1.2 Instrumentation*

Instrumentation within the main dam includes piezometers, weirs a staff gauge, automated water level meters and CCTV cameras (that were replaced in November 2023). There are twelve standpipe piezometers in total, within nine casing installations as shown in **Figure B2** in **Appendix B**. Typical photos of the standpipe piezometers are shown in **Photographs JCR 25** and **JCR 26.** Water levels within the standpipes are measured and entered within the City's database as part of a bi-weekly monitoring program. Pneumatic piezometers used to be monitored; however, this has been abandoned due to inconsistent and erratic readings, and data is no longer collected.

Five 'V' notch weirs ('A' to 'E') are used to monitor seepage at the downstream toe of the main dam at locations shown in **Figure B2** in **Appendix B**. Seepage weir readings taken the week of the inspection by City Dam Inspectors are summarized in **Table 4-4**. Images of the weirs at the time of inspection are shown in **Photographs JCR 27** to **JCR 31**.

**Table 4-4: Seepage Weir Readings (cm) September 8, 2023)**

| Weir | September 8, 2023 (as per Appendix D) | September 26, 2023 (measured during site visit) |
|---|---|---|
| Weir A | 1.7 | 2 |
| Weir B | 0 | 1 |
| Weir C | 0 | 0.2 |
| Weir D | 0 | 1.5 |
| Weir E | 0 | 1 |

None of the existing instruments are automated. Instrumentation readings are manually obtained approximately two to three times per week. The current frequency of instrumentation monitoring is appropriate and satisfies the requirements of the BC Dam

Safety Regulation. The City reviews the readings on a monthly basis. Weir measurements are variable due precipitation and runoff influence.

The 2016 FADI recommended the retrofit of existing standpipe piezometers with real-time automated vibrating wire (VW) piezometers. Vibrating wire piezometers can be connected to an automatic data acquisition system (ADAS) and allow for higher data resolution (lower reading intervals), real-time identification of changes or potential development of dam safety issues and enhanced remote monitoring. As part of the 2022 FADI, the 2016 recommendation was updated to state that VW retrofits of the existing standpipe piezometers may be considered if adverse or changing trends in instrumentation measurements occur. Alternatively, VW piezometers may also be considered to reduce City of Nanaimo staff workload associated with manual instrumentation measurements.

Additional piezometers were found downstream of the Main Dam and Auxiliary Spillway which were not owned by the City and were apparently installed for soil investigations for potential dam upgrading purposes. It is recommended to gather the installation details and initiate monitoring those as an additional source of information.

CCTV cameras were replaced on November 16th, 2023, by the City of Nanaimo which allows live streaming of the dam crest and reservoir, still photos and 360° view of the area from the City's offices.

### *4.1.3 Formal Inspection*

The Jump Creek Dam was in similar condition to that reported during the 2022 FADI. Visual inspections were performed by walking the crest of the Main Dam and Auxiliary Dam, observing the upstream and downstream faces, walking the toe of the Main Dam and Auxiliary Dam, walk the left and right sides of the concrete spillway, and observing the reservoir from the crest of the dam. The water level was below the spillway invert, allowing visual inspection of concrete walls and floor inside the spillway chute. Review of the upstream side of the dam was limited to the area above the waterline. Visual inspection and sounding inside the LLO was also carried out. The following key observations were made during the inspection:

#### *4.1.3.1 Main Dam*

4.1.3.1.1 Upstream Face

- There was no sign of cracking or slope instability along the upstream slope of the dam during the inspection.
- The upstream slopes showed no sign of erosion or beaching. No settlements or depressions of concern were noted **(Photograph JCR 1)**.
- Riprap on the upstream face was only inspected above the waterline which corresponded to a larger area than in previous inspections due to the lower reservoir level. Riprap coverage appeared continuous apart from select zones of low coverage, smaller size rock particles (compared to the mean size), and lack of strong particle interlocking

(**Photograph JCR 35**). Some areas at the bottom of the exposed riprap were found to be mainly comprised of smaller rock particles **(Photograph JCR 1)**. The riprap thickness varies from approximately 0.3 m thick. Riprap diameter ranges between 0.1 m to 1.5 m with a mean size of approximately 0.5 m. Zones of low coverage and lack of interlocking were specifically observed left of piezometer SP12. Zones of low coverage and smaller rock size should be monitored, and consideration given to rehabilitate the riprap protection in those areas.

- Minor vegetation growth was noted in the freeboard zone (**Photographs JCR 6, JCR 34 and JCR 35**). It is recommended that vegetation be cleared (including roots) and voids backfilled to mitigate potential riprap dislodgement due to vegetation growth and improve visibility of the upstream face for inspections.
- Wood debris deposition was noted on the upstream face which is removed and burned by City staff as part of the annual maintenance program. This annual maintenance was performed in the fall following the site visit when the fire danger rating is low.

4.1.3.1.2 Crest and Abutments

- The crest was in satisfactory condition at the time of inspection. There were no cracks, settlements, or sinkholes observed on the dam crest and no signs of erosion or unusual conditions at this stage along the dam crest. Minor rutting of the road topping material was noted where water had accumulated due to the rainy weather.
- No seepage or signs of movement were observed at either the left or right abutment of the dam. Large trees (10+ m high) were noted along both abutments where the dam blends into the natural environment.
- The upstream face of the left abutment steepens to approximately 1H:1V over a 15 m length. It is recommended that the City monitor this over-steepened section, conduct a survey of the area, and compare to past year's survey to determine if movement is advancing. As described in the 2022 FADI, high water levels have eroded soil cover where the riprap meets the abutment at shoreline. This has created erosional scour approximately 0.3 m to 0.5 m high (**Photograph JCR 39**). During the 2023 FADI, this scour was observed to have similar dimensions. This should be monitored, and consideration given to placement of rockfill and riprap to mitigate erosion if conditions worsen.

4.1.3.1.3 Downstream Face and Toe

- The downstream face and toe of the dam were noted to be in satisfactory condition. The downstream face appears to be comprised of shell materials with gravels and cobbles up to 0.3 m diameter. No evidence of slide movements, settlement or displacement, cracking, sinkholes, piping, or ejecta were observed.
- Some sparse, low-lying vegetation growth was observed on the downstream face. Minor vegetation (e.g., grass and weeds) should be trimmed to allow inspection of the dam

face. Removal of the root system is not necessary for small, grass-like vegetation. Brush and trees should be removed (including the root system) and the void backfilled.

- Bulging near the at the downstream toe of the dam was first documented in the 2017 FADI report (**Photograph JCR 37**). The bulge is located approximately 50 m left (north-west) of the LLO and approximately one-third of the slope height above the toe. Surveying pins have been installed and are surveyed once a year by the City and do not appear to have been changing with time. The bulge is not accompanied by slumping at the slope crest or signs of seepage and is therefore not considered to have formed due to slope instability or slumping. The bulge likely dates back to the original dam construction. Survey monitoring should be continued on an annual basis. However, the visual inspection shows there are not any changes in bulge condition from the 2022 inspection.
- Ponded seepage, saturated conditions, and vegetation overgrowth were noted on the downstream face and toe near the left abutment. The seepage location corresponds with the section where the dam is highest (25 m) and is located over the historical watercourse for Jump Creek. This seepage is considered dam seepage which has been collected by the downstream blanket drain and is expected to be captured by weirs A and C. The ponded seepage was clear with no signs of material migration.
- Toe seepage is monitored by five 'V-notch' weirs located downstream of the toe **(Photographs JCR 27 to JCR 31)**. All weirs were flowing at the time of the inspection, possibly due to surface runoff from the rain. Discussions with City staff indicate that Weir A is the only weir which is consistently subjected to flow, as shown by the measurements taken the week of September 8, 2023 in which Weirs B to E had no flow as per **Table 4-4**.
- Seepage on the downstream face could not be observed during this inspection due to active rain fall; however, the 2022 FADI report indicates some seepage, soft ground, rust discolouration, and vegetation was observed on the downstream face of the dam (near the right abutment) approximately 50 m downstream of the crest and 10 m to the right of the spillway. The seepage appeared to be toe seepage daylighting at the downstream toe of the dam which is only 7 m high in this area **(Photograph JCR 32)**. The construction of a new V-notch weir was recommended to capture and monitor this seepage.
- As described in the 2020 FADI report, a wet spot approximately 1 m in diameter was observed on the lower access road just upstream of Weir E (see location marked on **Figure B2** in **Appendix B**). During the 2023 inspection, this area was observed to be wet due to the rain and have a light rust discolouration, but no ponding was observed **(Photograph JCR 33)**. Going forward, this area should be closely monitored at the same time as data is collected at Weir E. If active seepage is observed and if the seepage is cloudy, and/or if earth material starts to bulge in this location, dam safety personnel should be notified immediately.

#### *4.1.3.2 Main Spillway*

- The main spillway structure was generally observed to be in fair condition and no major changes in condition were observed since the 2022 FADI. Small pieces of debris were observed inside the spillway chute at the time of the inspection (**Photographs JCR 12 to JCR 15**).
- Inside of the spillway chute was wet and slippery due to rainfall at the time of inspection and the concrete structure was inspected from outside of the chute. Some reinforcing bars were exposed along the spillway chute slab and walls and it was recommended that these areas be patched with repair mortar to protect the bars from further corrosion in the future.
- Areas of spalling were observed at the construction joints along the spillway slab (**Photograph JCR 12**). Spalls up to 100 mm wide were observed. Calcite staining was noted at many of the construction joints along both the spillway slab and walls, which could be an indication of past seepage through the joints. Sign of seepage could not be observed due to rainfall during the inspection but some seepage was observed along the slab at the downstream construction joints in 2022 FADI. It is recommended that the areas around the construction joints continue to be monitored to detect any additional concrete deterioration or seepage over time.
- Minor concrete erosion and minor cracking was also noted at the base of each wall within the spillway. These areas should continue to be monitored and if any major spalling begins to occur, repair of these areas would be recommended.
- The spillway gates were fully open and could not be inspected during this inspection; however, the 2022 FADI indicates the downstream side of the spillway gates were inspected and were generally observed to be in fair condition. As indicated in 2021 FADI report, one vertical strut on the right gate showed considerably more corrosion than any of the other struts on either gate, though there was no notable section loss. This corrosion could be due to a small leak or crack along the weld; however, no defect was found during the visual inspection. It is recommended that the corrosion be monitored and if it advances further, recoating of the gate in that area would then be recommended. It is also recommended that the gate leakage be monitored when the gate is retaining water in the raised position to determine if any leakage around the strut is noticeable.
- The steel grating panels in spillway deck were observed to be in fair condition and steel angles were installed along both sides of the grating to prevent vehicles from driving over the grating since these grating panels were likely not designed for vehicle loading (**Photograph JCR 7**). All steel members and grating panels on the spillway deck were repainted recently.
- Minor cracking was observed in the central pier, primarily originating from the square block-out section. This has been noted for several years and does not appear to have changed based on a review of annual photos. These cracks are not considered a

concern at this time but should be monitored as part of routine inspections and future FADIs. It is recommended that the crack length be marked and dated so that advancement of the crack can be easily tracked and monitored using the Mobile Dam Inspection Database.

- Minor vegetation growth was observed adjacent to the spillway and spillway chute. It is recommended to cut back and clear the vegetation from the area. This clearing work should continue to be completed as a part of the annual vegetation control program.

#### *4.1.3.3 Log Boom*

- The log boom was generally in satisfactory condition as it was replaced in July 2019. The boom was observed from both shorelines adjacent to the anchors (**Photographs JCR 3 and JCR 16**).
- The chain connecting the existing anchor block to the new right anchor grouping was not taut (**Photograph JCR 2)** and therefore will not equally load the entire anchor assembly when engaged. The anchor chain has been tightened since original installation, but still needs to be tightened so the new anchor assembly is engaged when the log boom experiences loading from debris.
- Chain clamps were replaced as needed in 2022 when the reservoir level was low which allowed repair work at the log boom from the surface. Surface corrosion was observed on some hardware used to tie-down the log boom and should be monitored and replaced if needed.

#### *4.1.3.4 Low Level Outlet*

Normal water flows through the low-level outlet (LLO) were set to approximately 20 $ft^3/s$ at the time of inspection **(Photograph JCR 22)**. The condition review of the LLO was limited to the portions of the intake structure and outlet structure above the water level.

- The conditions within the LLO tunnel were not reviewed during this inspection; however, the 2021 FADI report indicates that the tunnel concrete in general was observed to be in fair condition with areas of rust staining and calcite deposits on the walls and roof of the tunnel.
- The condition of the LLO concrete outlet structure was in satisfactory condition for all concrete above the water level. The condition of the intake structure was also observed to be in satisfactory condition.
- Some minor vegetation growth was observed near to outlet channel, mainly on the right bank of the channel and it is recommended to remove all vegetation from the edges of the channel and continue cleaning this area as part of the annual vegetation control plan.

The inspection also included the inlet works on the upstream side of the dam (**Photograph JCR 18)** and the following observations were made.

- TheLLO intake concrete, cover and the metal straps supporting it were observed to be in fair condition. Small wooden debris was observed to be wedged on the headwall of the intake structure along the intake cover. It is recommended that this debris be removed as a part of the general maintenance of the dam.
- The bolts, nuts, and washers for parts of the steel structure were showing signs of surface corrosion. It is recommended that the corrosion continued to be monitored and if section loss is observed, the affected hardware should be replaced. However, it is noted that the condition of this structure was similar to the 2022 inspection.
- There was minor undermining of the bottom of the concrete block for the LLO gate, which should continue to be monitored.

#### *4.1.3.5 Auxiliary Spillway*

- The crest of the auxiliary spillway was visually reviewed and was found to be in satisfactory condition without any major defects or differential settlement between concrete blocks (**Photograph JCR 45**). Some surface deterioration (minor spalling and weathering) due to freeze-thaw action is visible. The deterioration is being monitored as part of Mobile Dam Inspection Database and City Dam Inspectors numbered the top of the blocks in 2022 and will continue to track the condition of the blocks with photographic records over time. However, no significant changes were observed in the condition of the concrete blocks since 2020 FADI.
- Riprap is interlocked and in good condition on the upstream slope (**Photograph JCR 40 and JCR 41**). Two zones of sparse riprap coverage with exposure of the underlying coarse filter were noted on the downstream slope of the auxiliary spillway near the right abutment wing wall (**Photograph JCR 42 and JCR43**). Additional riprap should be placed as per the original design to protect the filter from erosion.
- Minor wood debris has collected at the upstream face of the dam. This debris is removed by the City as part of the annual maintenance program.
- It has previously been recommended to read the existing piezometer located downstream of the downstream access road. This piezometer is not owned by the city. The downstream water table is anticipated to be near the surface based on the presence of the downstream swamp and observed seepage at the downstream toe. Monitoring of the existing piezometer is not required.
- Wet zones were observed at the toe of the downstream slope. It is expected that more surface water was observed than usual due to the heavy rain. Nevertheless, these wet zones were consistent with the minor seepage noted during FADI 2022 below the energy dissipator concrete block in the cobbles at the downstream toe **(Photograph JCR 44)** as well as some behind the concrete sill. City dam inspectors noted that the water never flows over the concrete sill at the downstream toe.

#### 4.1.3.6 *Reservoir*

A visual review of the reservoir and surrounding basin area was made from the crest of the main dam and the auxiliary dam.

- No sign of instability that could lead to overtopping was observed. However, a full inspection of the reservoir rim was not carried out at this time.
- There was a landslide scar on the east slope of the reservoir adjacent to the Spillway. The landslide washed out part of the access road in 2018. Landslide propensity poses a potential landslide risk to the Spillway and dam.
- The stream gauge at the crossing of the dam access road and Jump Creek was not visited during in this inspection, but City Staff confirmed that it is still broken and should be replaced as noted in the 2022 FADI.

#### 4.1.3.7 *Public Safety*

There is no public access to this dam as it is only accessible by private logging roads with a number of locked gates to restrict access. The City supervises school tours to the dam, but there is no non-supervised public presence at this site. Therefore, public safety control measures were not considered at this time.

### *4.1.4 Recommendations*

The following surveillance/rehabilitation work is recommended for Jump Creek Dam as shown in **Table 4-5**. Some of these items are carried over or modified from previous FADIs.

**Table 4-5: Jump Creek Dam – Surveillance/Rehabilitation Recommendations**

| Item | Description | Reference |
|---|---|---|
| JCR 1.01 | Monitor the cracks observed in the piers at the top of the spillway below the road deck as part of the Mobile Data Inspection Database. This should include photographic records and mapping the length of the cracks and the width of the cracks at select locations. This should be done on a quarterly basis and be reviewed annually as part of the FADI.<br>2022 Update: Mark the crack lengths in the piers to establish baseline for future comparison. Once the baseline is established, this item can be closed and can be monitored as part of annual inspections. | 2017 FADI (Modified 2022) |
| JCR 1.02 | Identify areas with exposed rebar along the spillway chute slab and walls and perform localized repairs. | 2021 FADI |
| JCR 1.03 | Install one additional ‘V’ notch weir at toe of right abutment to monitor seepage. | 2017 FADI |
| JCR 1.04 | Tighten chain connection between existing right anchor block and new right anchor group so connection is taut.<br>Tightened in early 2020, but still has some sag in chain. | 2020 FADI |

| Item | Description | Reference |
|---|---|---|
| JCR 1.05 | Monitor areas of poor to fair condition riprap on upstream face of main dam. Consider rehabilitation of deficient areas if conditions worsen, to infill depressions, ensure full coverage, achieve strong interlock, and avoid future movement/slumps. | 2021 FADI |
| JCR 1.06 | Place additional riprap to fill a zone of sparse riprap coverage (with underlying coarse filter exposed) on the downstream slope of the auxiliary spillway near the right abutment wingwall.<br>2023 Update: A second zone of sparse riprap was noted and should also be repaired by placing additional riprap. | 2022 FADI<br>(Modified 2023) |
| JCR 1.07 | The stream gauge at the crossing of the dam access road and Jump Creek is broken and should be replaced. | 2022 FADI |
| **Recommendations to Close** | | |
| | Update OMS manual to include log boom changes. Currently OMS manual states that there are two log booms.<br>2023 Revision: Close this recommendation. OMS manual was updated to include log boom changes. | 2020 FADI |
| | Monitor the corrosion and potential leakage around the gate strut identified during the inspection. If the corrosion advances in the future, repair of the gate coating should be considered.<br>2022 Revision: Close this recommendation. Condition of spillway gates will continue to be monitored during annual inspections.<br>2023 Revision: As the gate was fully open during 2023 site inspection, the corrosion and leakage around the gate strut could not be monitored as recommended in previous FADI. | 2021 FADI |

## 4.2 South Fork (SFK)

### *4.2.1 Dam Description*

The South Fork Dam is located approximately 18 km southwest of Nanaimo and 9.7 km downstream of the Jump Creek Dam on the South Nanaimo River. The dam, which is essentially an overflow weir structure, is a concrete arch dam constructed in 1931 to provide water supply to the City of Nanaimo. The reservoir is maintained at its Full Supply Level (FSL) in order to maintain pressure in the two water supply watermains. The intake of the 1.2 m and 0.75 m water supply mains are located on the left abutment immediately upstream of the dam.

The dam is situated in a steep bedrock canyon, is 30.5 m high at its highest point, and has a total crest length of 65.4 m, of which 50.6 m is a free overflow crest spillway that discharges into a natural plunge pool. The dam is a variable radius non-reinforced concrete arch structure that has not been structurally modified since construction. The outer radius is 29.7 m at the crest and 21.5 m at its base. The thickness of the arch increases from 0.9 m at the crest to 2.1 m at its base. Horizontal construction lift joints are spaced at about 1.5 m and a vertical pressure grout joint is located at the centerline of the dam. See **Figure B4** in **Appendix B** and **Table 4-6** for the dam details.

The log boom, approximately 1 km upstream of the dam, failed in 2019 and was not reinstated as debris will pass over the spillway during high flow events, and is therefore not considered to be a dam safety concern. A glance boom was installed in 2019 at the water intake to help prevent debris from floating in the vicinity of the inlet pipe. The boom is a double log boom arrangement fabricated using new unpeeled logs. The boom is anchored to the rock at the upstream and downstream ends and held in position with wire rope and is in satisfactory condition. The boom was installed with logs pre-drilled on land without the optimum buoyancy of the logs established.

Three inlet gates are used to control the reservoir water entering the water supply tunnel. The top inlet is not operated as a vortex is created when the gate is opened, and the bottom gate is not used due to the turbidity down near the bottom of the reservoir. Therefore, the middle gate is solely used to supply the water.

**Table 4-6: Data for South Fork Dam and Appurtenant Structures**

| Structure | Details |
|---|---|
| Type of Dam | Variable Radius Concrete Arch Dam |
| Maximum Height | 30.5 m |
| Crest Length | 65.4 m |
| Crest Width | N/A |
| Crest Elevation | 250.32 m |
| Storage Volume | 2,000,000 $m^3$ |
| Inlet and Outlet Works | Intake immediately upstream of dam, water supply tunnel on left abutment, two outlets water supply main 1.2 m diameter and 0.75 m diameter |
| Spillway | Overflow spillway over the crest, overflow crest length 50.6 m |
| Hazard Rating | Very High |

### *4.2.2 Instrumentation*

Instrumentation pertaining to dam safety at the South Fork Dam are the lake level gauges, which are monitored weekly and continually recorded on SCADA, and the newly installed CCTV cameras. During extreme events (reservoir elevation 2.5 m above crest or higher), the flows levels are checked every 3 hours. The water level was slightly above the dam crest at the time of the inspection.

There is also a 'V' notch weir located downstream of the dam at the entrance to the water supply tunnel.

CCTV cameras were installed on November 10th, 2023. The cameras allow for continuous surveillance and data recording as well as still photos. City personnel mentioned that there seemed to be issues with the camera movement at South Fork and that trees were cut down at the end of November to help with this issue.

### *4.2.3 Formal Inspection*

The South Fork Dam was in similar condition to that reported during the 2022 FADI. Visual inspections were performed by walking the north shore adjacent to the dam. The south shore was not accessed during the inspection. Water was flowing over the dam at the time of the inspection which limited the extent of the inspections. The following observations were made during the inspection:

#### *4.2.3.1 Abutments*

- The left and right abutments of the dam are composed of bedrock and were in fair condition. At the time of the inspection, the interface between the dam and abutments was partially covered with water flowing over the dam crest. The bedrock at the right abutment was found to be partially covered by moss and vegetation. Exposed areas were fresh to slightly weathered and of satisfactory quality and no changes were observed from the previous inspection in 2022. The rock above the right abutment was observed from across the channel to have subvertical joint faces during the 2020 inspection. Loose blocks approximately two-thirds of the way up the dam at the abutment were satisfactorily scaled and removed (**Photographs SFK 5** and **SFK 6**).

- The concrete-bedrock contact at the right abutment was observed from the left abutment and seemed in fair condition with some minor alteration and loose rock flakes (**Photograph SFK 5**). The presence of moss and vegetation at that location limited the observation of the area. Any growths in that location should be cut and controlled to allow proper inspection. The rock upstream of the left abutment, above the dam crest elevation, was observed to be poor to fair condition (**Photographs SFK 13 and SFK 14**).

- Detached rock blocks near the intake access penstock upstream of the left abutment were observed between 1 $m^3$ to 6 $m^3$ with full length tensions cracks on shallow sliding discontinuities. Assessments of rock wedges are considered necessary for long term operation and safe access of the dam left abutment. One large rock block (**Photograph SFK 14**) may be prone to toppling or sliding due to the vertical tension crack to the left of the block. No obvious movement was observed since 2022 FADI. The rock block should be monitored after heavy rainfall events for movement or signs of instability. The rock block may pose significant risk to the underwater intake penstock, and if motion or further instability is observed, may require removal.

- Small rockfalls from behind the protective mesh (rocks <0.2 m in size) were observed at the toe of the slope on the left side of the downstream channel (**Photograph SFK 12**).

- The concrete block and access ramp at the left abutment was observed to be in fair condition with some cracking and spalling noted on the upstream face. Calcite staining was also observed at this location. No change in concrete condition was noticed since the last year inspection.

*4.2.3.2 Crest and Reservoir*

- At the time of the site visit, the reservoir level was slightly above the dam crest and was flowing over the crest into the plunge pool downstream.
- The concrete at the dam crest appeared to be in fair condition and the immediate upstream reservoir area was free of debris with only one log observed lodged against upstream side of dam crest. Now that the debris boom has been permanently removed, debris is expected to regularly flow over the dam crest during high flow events (**Photographs SFK 1** and **SFK 5**).

*4.2.3.3 Downstream Face*

There was water flowing over the dam crest at the time of inspection and it prevented a visual inspection of the downstream concrete face of the dam **(Photograph SFK 7)**. However, the 2020 drone inspection during no flow conditions noted that the concrete on the downstream face of the dam was in fair condition without any major deterioration or sign of movement in the lift joints. No significant change is expected in the condition of concrete since 2020 from previous site inspection. As seasonal low reservoir level sometimes allows the operation staff to see the downstream face, it was discussed that the use of a drone (as has been used in the past) to capture images could benefit the annual inspection of dam and its downstream face.

*4.2.3.4 Log Boom*

The log boom was observed to be well positioned near the left shoreline immediately upstream of the dam to provide protection for the water inlet pipes (**Photograph SFK 4**). The log boom appeared to be in satisfactory condition and the floatation of the logs appeared adequate at the time of the inspection.

4.2.3.5 *Inlet Gates*

The inlet gates could not be visually inspected on site. An underwater dive inspection of the gates was performed by a third party on May 4, 2020. It was noted that there was a significant amount of organic growth on the cylinders and brackets. A safety chain was installed on the middle gate to provide system redundancy should the gate hydraulics fail as this is the only active gate. There was significant corrosion on the gate components and pitting around the lip of the intake observed during the underwater inspection.

*4.2.3.6 Water Supply Tunnel*

- The tunnel was found to be in satisfactory condition. Shotcrete was observed in satisfactory condition on the fractured rock face at the entry to the tunnel to limit the potential for debris falling into the tunnel and onto the steel water supply pipe. Cracks observed in the shotcrete facing above the entrance to the supply tunnel should continue to be monitored for signs of further cracking by using spray paint along the existing length. Spreading/separation of the cracks should also be monitored using a crack gauge.

- The tunnel inspection involved access into the tunnel on the left-hand side of the water supply pipe from the downstream end. The majority of the tunnel face appeared to be composed of hard, sound rock with minimal risk of loose fragments falling from above. As reported in 2022 FADI, one rock block was observed overhead, approximately 4 m into the tunnel on the righthand side of the water supply pipe, that was delineated by joints. This area should be marked/identified and monitored as it may present a safety hazard in the future if movement is noted during future inspections.
- Discontinuities were generally tight, however, a few local, clay infilled discontinuities are favorably oriented perpendicular and sub-vertical to the tunnel alignment. A local shear or clay-filled discontinuity sub-parallel to the left wall was observed to be actively spalling approximately halfway into the tunnel (on the tunnel wall just before the fourth concrete footing on the lefthand side of the water supply pipe encountered from the entrance of the tunnel). Some loose rock was observed at the toe of the wall near this discontinuity (**Photograph SFK 15**). This area should be marked/identified, monitored for continued spalling and should not be further disturbed by accessing personnel. Beyond this zone, the typical competent rock was observed.
- Six rock bolts were observed approximately 5 m from the end of the tunnel (i.e., near the upstream end). This area should be marked/identified and tunnel conditions should continue to be monitored during routine inspections and future FADIs. The rock was found generally tight and generally dry to damp conditions outside of the portal area. Minor seepage was observed within 5 m of the portal during the inspection up to the end of the tunnel.
- The steel pipe and concrete anchor blocks were found to be in fair condition (**Photograph SFK 9**). There was some staining of the concrete around the water level at the base of the tunnel and some spalling was observed on a couple of the anchor blocks, however these are not considered to be a major concern at this time. It should be monitored, and concrete repair is required in deficient areas if conditions worsen.

#### *4.2.3.7 Miscellaneous*

- During the 2016 FADI, the condition of the access road that leads down to the toe of the dam was identified as a potential stability issue. In particular, there was an observed narrowing of the road over a relatively large steel culvert. The erosion did not appear to have advanced significantly since the previous inspection. It is recommended that the culvert continue to be monitored and if erosion and sloughing of the roadway continues, then a concrete headwall or other reinforcing measure should be implemented.
- As noted during the 2018 FADI, the inlet supply tunnel platform is constructed on wood planks resting on top of the steel support beams used to stabilize the inlet ventilation piping. The platform is sloped away from the channel towards the rock face. During rain events, this platform gets very slippery and is considered a slip hazard for City staff.

During the 2023 inspection, the wood platform was found to be slippery due to recent rain and soft in some areas indicating it might be rotten.

#### *4.2.3.8 Public Safety*

Similar to Jump Creek Dam, there is no public access to this dam as it is only accessible by private logging roads with a number of locked gates to restrict access. The City supervises school tours to the dam, but there is no non-supervised public presence at this site. Therefore, public safety control measures were not considered at this time.

### *4.2.4 Recommendations*

The following surveillance/rehabilitation work is recommended for South Fork Dam as shown in **Table 4-7**. Some of these items are carried over from previous FADIs.

**Table 4-7: South Fork Dam – Surveillance/Rehabilitation Recommendations**

| Item | Description | Reference |
|---|---|---|
| SFK 1.01 | Install an anti-slip surface on inlet supply tunnel platform.<br>2023 Revision: Replace inlet supply tunnel platform as wood platform was found to be slippery and soft in some areas indicating it might be rotten. | 2017 FADI<br>(Modified 2023 FADI) |
| SFK 1.02 | Monitor for movement of rock wedges on the upstream side of the left abutment.<br>2022 Revision: The rock wedge presents a hazard to personnel using the nearby ladder or accessing the debris boom. Rock fall hazard should be mitigated which could include scaling or removal of the wedge, rock support, or prohibit access to the area. | 2019 FADI<br>(Modified 2022) |
| SFK 1.03 | Remove the vegetation growth within the lift joint cracks on the downstream face of the dam structure. | 2021 FADI |
| SFK 1.04 | Remove the vegetation growth at the right abutment upstream of the dam to allow proper inspection of the concrete-bedrock interface. | 2023 FADI |
| SFK 1.05 | Identify and mark two main areas, the local shear or clay filled discontinuity sub-parallel to the left wall (around the fourth concrete footing from the tunnel entrance) and the rock block (approximately 4 m into the tunnel) to facilitate continued inspection and monitoring. It is recommended these areas be marked during the 2024 DSR. | 2023 FADI |
| **Recommendations to Close** | | |
| | Measure crack width of shotcrete facing above the entrance to the tunnel by installing survey nails in a triangular pattern into the rock across the crack face. Log photographs to monitor any crack progression. This should be performed as part of the routine inspections as included in the Mobile Dam Inspection Database.<br>2023 Revision: Close this recommendation. The cracks are being monitored with paint and pictures. | 2015 FADI |

| Item | Description | Reference |
|---|---|---|
| | Backfill void in gravel/riprap along access road at downstream left side of channel. Void currently presents tripping hazard to personnel.<br>2023 Revision: Close this recommendation. No voids or tripping hazards observed. | 2020 FADI |

# 5. Summary

There are two types of recommendations summarized below:

1. Outstanding surveillance and rehabilitation recommendations were summarized from previous FADI and new recommendations were made. See **Table 5-1**.
2. Outstanding dam safety recommendations originating from previous DSRs that were in the City's Dam Safety Issues tracking spreadsheet were summarized. See **Table 5-2**.

Note that items in these tables are summarized and additional detail is provided in earlier sections. Additionally, Hatch has attempted to summarize all previous outstanding recommendations; however, it is the City's responsibility to ensure that all previous recommendations have been prioritized and addressed to their satisfaction.

Hatch understands that the City has limited resources. Therefore, it is extremely important to prioritize the various recommendations so the City can create a plan for addressing/resolving these deficiencies. Priority ratings have been added for each item where:

A = high priority (complete within 2 years);

B = medium priority (complete within 5 years); and

C = low priority (complete within 10 years/reassess with changing conditions).

**Table 5-1: Summary of Surveillance and Rehabilitation Recommendations**

| Item | Description | Reference | Priority |
|---|---|---|---|
| GENERAL 1.01 | Convert elevations to flow on seepage plots. | | A |
| JCR 1.01 | Monitor the cracks observed in the piers at the top of the spillway below the road deck on a quarterly basis as part of the Mobile Data Inspection Database.<br>2022 Revision: Mark the crack lengths in the piers to establish baseline for future comparison. Once the baseline is established, this item can be closed and can be monitored as part of annual inspections. | 2017 FADI (Modified 2022) | A |
| JCR 1.02 | Identify areas with exposed rebar along the spillway chute slab and walls and perform localized repairs. | 2021 FADI | B |
| JCR 1.03 | Install one additional 'V' notch weir at toe of right abutment to monitor seepage. | 2017 FADI | A |

| Item | Description | Reference | Priority |
|---|---|---|---|
| JCR 1.04 | Tighten chain connection between existing right anchor block and new right anchor group so connection is taut. | 2020 FADI | A |
| JCR 1.05 | Monitor areas of poor to fair condition riprap on upstream face of main dam. Consider rehabilitation of deficient areas if conditions worsen, to infill depressions, ensure full coverage, achieve strong interlock, and avoid future movement/slumps. | 2021 FADI | A |
| JCR 1.06 | Place additional riprap to fill a zone of sparse riprap coverage (with underlying coarse filter exposed) on the downstream slope of the auxiliary spillway near the right abutment wingwall.<br>2023 Revision: A second zone of sparse riprap was noted and should also be repaired by placing additional riprap. | 2022 FADI (Modified 2023) | A |
| JCR 1.07 | The stream gauge at the crossing of the dam access road and Jump Creek is broken and should be replaced. | 2022 FADI | B |
| SFK 1.01 | Install an anti-slip surface on inlet supply tunnel platform.<br>2023 Revision: Replace inlet supply tunnel platform as wood platform was found to be slippery and soft in some areas indicating it might be rotten. | 2017 FADI (Modified 2023 FADI) | A |
| SFK 1.02 | Monitor for movement of rock wedges on the upstream side of the left abutment.<br>2022 Revision: The rock wedge presents a hazard to personnel using the nearby ladder or accessing the debris boom. Rock fall hazard should be mitigated which could include scaling or removal of the wedge, rock support, or prohibit access to the area. | 2019 FADI (Modified 2022) | A |
| SFK 1.03 | Remove the vegetation growth within the lift joint cracks on the downstream face of the dam structure. | 2021 FADI | B |
| SFK 1.04 | Remove the vegetation growth at the right abutment upstream of the dam to allow proper inspection of the concrete-bedrock interface. | 2023 FADI | A |
| SFK 1.05 | Identify and mark two main areas, the local shear or clay filled discontinuity sub-parallel to the left wall (around the fourth concrete footing from the tunnel entrance) and the rock block (approximately 4 m into the tunnel) to facilitate continued inspection and monitoring. It is recommended these areas be marked during the 2024 DSR. | 2023 FADI | A |

**Table 5-2: Outstanding Dam Safety Issues**

| Item | Description | Reference | Priority |
|---|---|---|---|
| | | | |
| JCR 2.02 | Perform stability analysis for dam and spillway with most recent horizontal ground acceleration of corresponding PGA. | 2013 DSR | B |
| SFK 2.01 | Stability analysis of dam and dam abutments needs to be checked for increased seismic coefficient.<br>2023 Revision: Seismic stability assessment of dam is underway and scheduled to be completed in 2025. | 2013 DSR | A |
| **Recommendations to Close** | | | |
| JCR 2.01 | Check total spillway capacity for PMF from MWH screening report.<br>2023 Revision: Nanaimo Dam Breach Assessment and Inundation Mapping (Hatch, 2020), Hatch File H361489-00000-228-230-0001 checked the spillway capacity. The Jump Creek Main Dam will have 0.4 m of freeboard during the PMF. | 2013 DSR | |

# 6. Cost Estimate

The cost estimate is an ASCE Class 5 (-50% to +100%) cost estimate that provides for engineering services and for maintenance/rehabilitation works where the scope of work is defined sufficiently to provide an estimate. Where an engineering study is required, the subsequent rehabilitation has not been estimated as this will be dependent on the findings the engineering report and detailed design.

**Table 6-1: Cost Estimate – Outstanding Surveillance and Rehabilitation Issues**

| Item | Description | Estimated Cost | Notes |
|---|---|---|---|
| GENERAL 1.01 | Convert elevations to flow on seepage plots. | N/A | By City staff |
| JCR 1.01 | Monitor the cracks observed in the piers at the top of the spillway below the road deck on a quarterly basis as part of the Mobile Data Inspection Database.<br>2022 Revision: Mark the crack lengths in the piers to establish baseline for future comparison. Once the baseline is established, this item can be closed and can be monitored as part of annual inspections. | N/A | Include in MDID |
| JCR 1.02 | Identify areas with exposed rebar along the spillway chute slab and walls and perform localized repairs. | $ 5,000 | Labour by City staff |
| JCR 1.03 | Install one additional ‘V’ notch weir at toe of right abutment to monitor seepage. | $ 1,000 | Labour by City staff |

| Item | Description | Estimated Cost | Notes |
|---|---|---|---|
| JCR 1.04 | Tighten chain connection between existing right anchor block and new right anchor group so connection is taut. | N/A | Labour by City staff |
| JCR 1.05 | Monitor areas of poor to fair condition riprap on face of upstream dam and rehabilitate if conditions worsen. | N/A | By City staff |
| JCR 1.06 | Place additional riprap to fill a zone of sparse riprap coverage (with underlying coarse filter exposed) on the auxiliary spillway near the right abutment downstream wingwall.<br>2023 Update: A second zone of sparse riprap was noted and should also be repaired by placing additional riprap. | $ 40,000 | Allowance for design and construction. Other zone was included in previous assessment cost. |
| JCR 1.07 | The stream gauge at the crossing of the dam access road and Jump Creek is broken and should be replaced. | $ 500 | By City staff |
| SFK 1.01 | Install an anti-slip surface on inlet supply tunnel platform.<br>2023 Revision: Replace inlet supply tunnel platform as wood platform was found to be slippery and soft in some areas indicating it might be rotten. | $ 20,000 | |
| SFK 1.02 | Monitor movement of the rock wedge on the upstream side of the left abutment.<br>2022 Revision: The rock wedge presents a hazard to personnel using the nearby ladder or accessing the debris boom. Prohibit access to the area or mitigate the rockfall hazard which could include scaling or removal of the wedge or rock support. | N/A | No cost associated with restricting access to the area. |
| SFK 1.03 | Remove the vegetation growth within the lift joint cracks on the downstream face of the dam structure. | $ 30,000 | Allowance. Will be dependant on access. |
| SFK 1.04 | Remove the vegetation growth at the right abutment upstream of the dam to allow proper inspection of the concrete-bedrock interface. | $ 20,000 | Access will be a challenge. |
| SFK 1.05 | Areas requiring monitoring in the water supply tunnel should be identified/marked to facilitate inspection and observations. | $ 100 | Labour by City staff |

**Table 6-2: Cost Estimate – Outstanding Dam Safety Issues**

| Item | Description | Estimated Cost | Comments |
|---|---|---|---|
| JCR 2.02 | Perform stability analysis for dam and spillway with most recent seismic parameters. | $ 75,000 | |
| SFK 2.01 | Stability analysis of dam and dam abutments for increased seismic coefficient. | | In progress |

# Appendix A
# Summary of Information Reviewed

| Item | Document Name | Date |
|---|---|---|
| 1 | Dam Mobile Database (pdf files from most recent routine inspections) | September 2023 |
| 2 | Jump Creek OMS Manual | October 2023 |
| 3 | South Fork Dam OMS Manual | July 2013 |
| 4 | 2022 Formal Annual Dam Inspections | April 2023 |
| 5 | 2021 Formal Annual Dam Inspections | June 2022 |
| 6 | 2020 Formal Annual Dam Inspections | February 2021 |
| 7 | City of Nanaimo – Dam Safety Management Program | July 2020 |
| 8 | City of Nanaimo – Dam Emergency Plan | November 2019 |
| 9 | Dam Safety Reviews for Jump Creek Dam & Saddle Dam, South Fork Dam, Reservoir No. 1 Dam, Westwood Lake & Saddle Dam | 2014 |
| 10 | City of Nanaimo – Dam Emergency Plan for Jump Creek, South Fork, Westwood, Upper Chase, Middle Chase, Lower Chase, Reservoir No. 1. Harewood, Witchcraft | November 2019 |
| 11 | Dam Emergency Plan (DEP) – McGregor Creek Dam, D720163 | January 2020 |
| 12 | Water Licence Amendment 114478 | June 2022 |

# Appendix B
# Figures

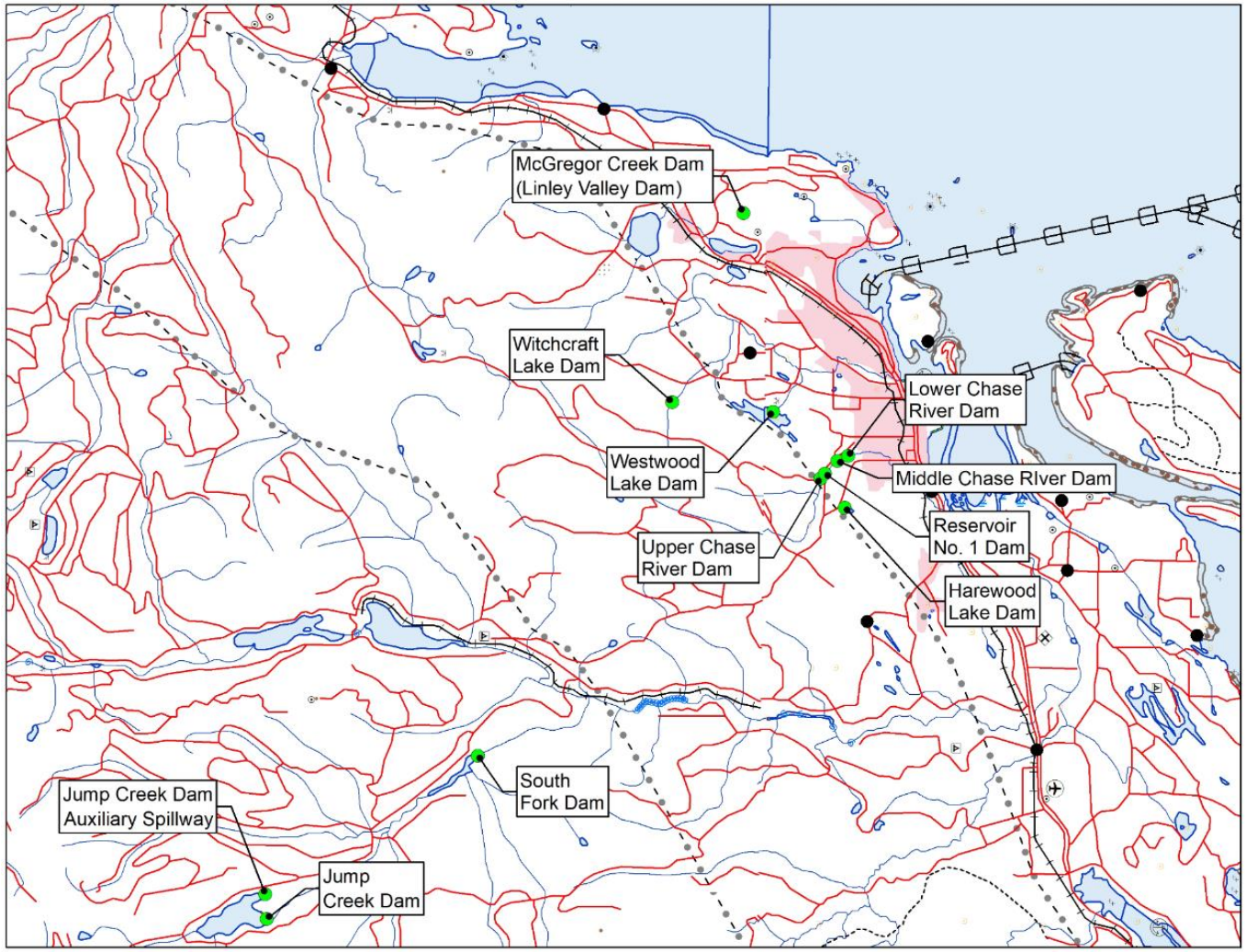



**Figure B1: Dam Locations**

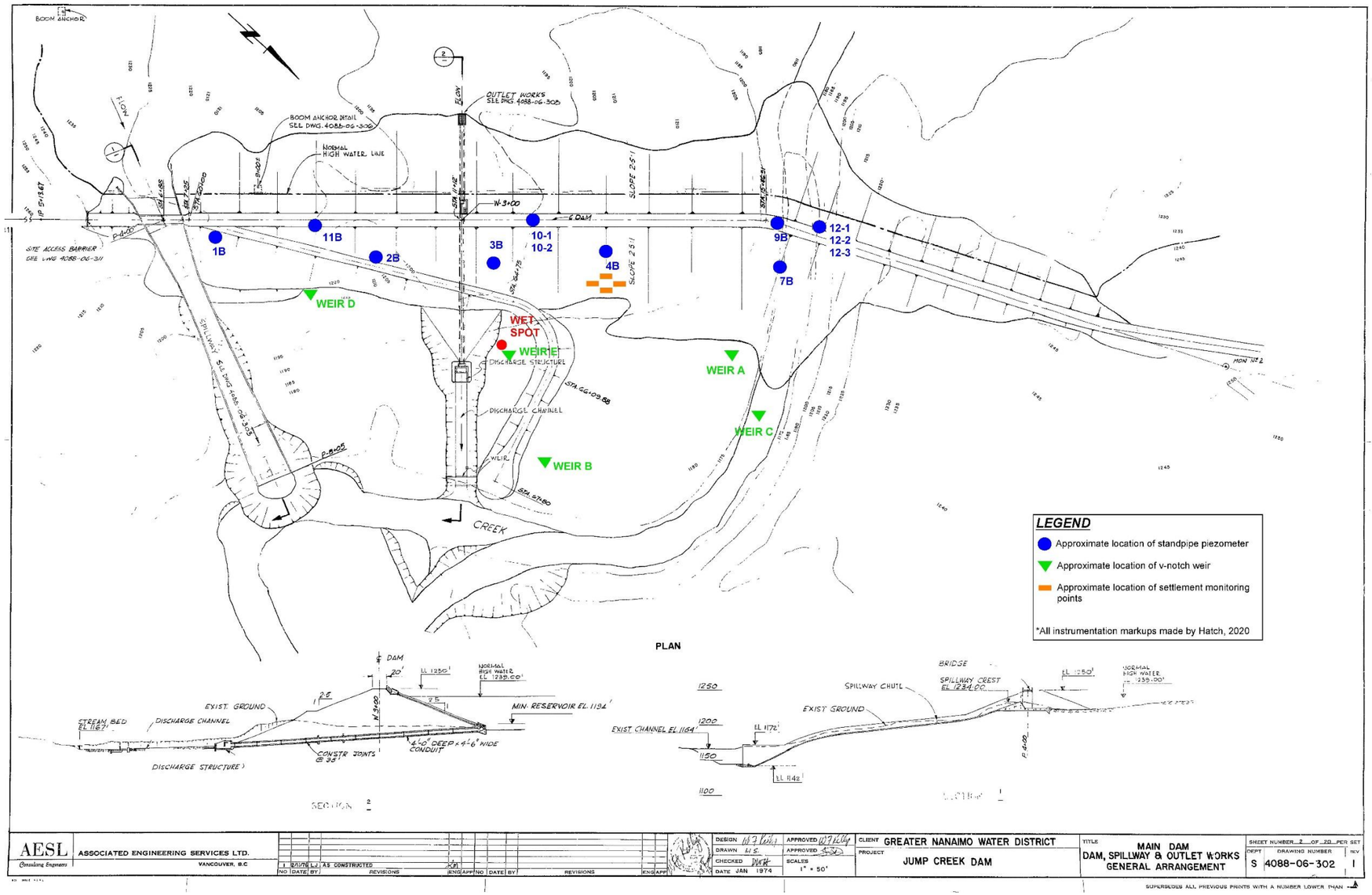



**Figure B2: General Layout of the Jump Creek Dam and Instrumentation (Figure Taken From 2014 DSR)**

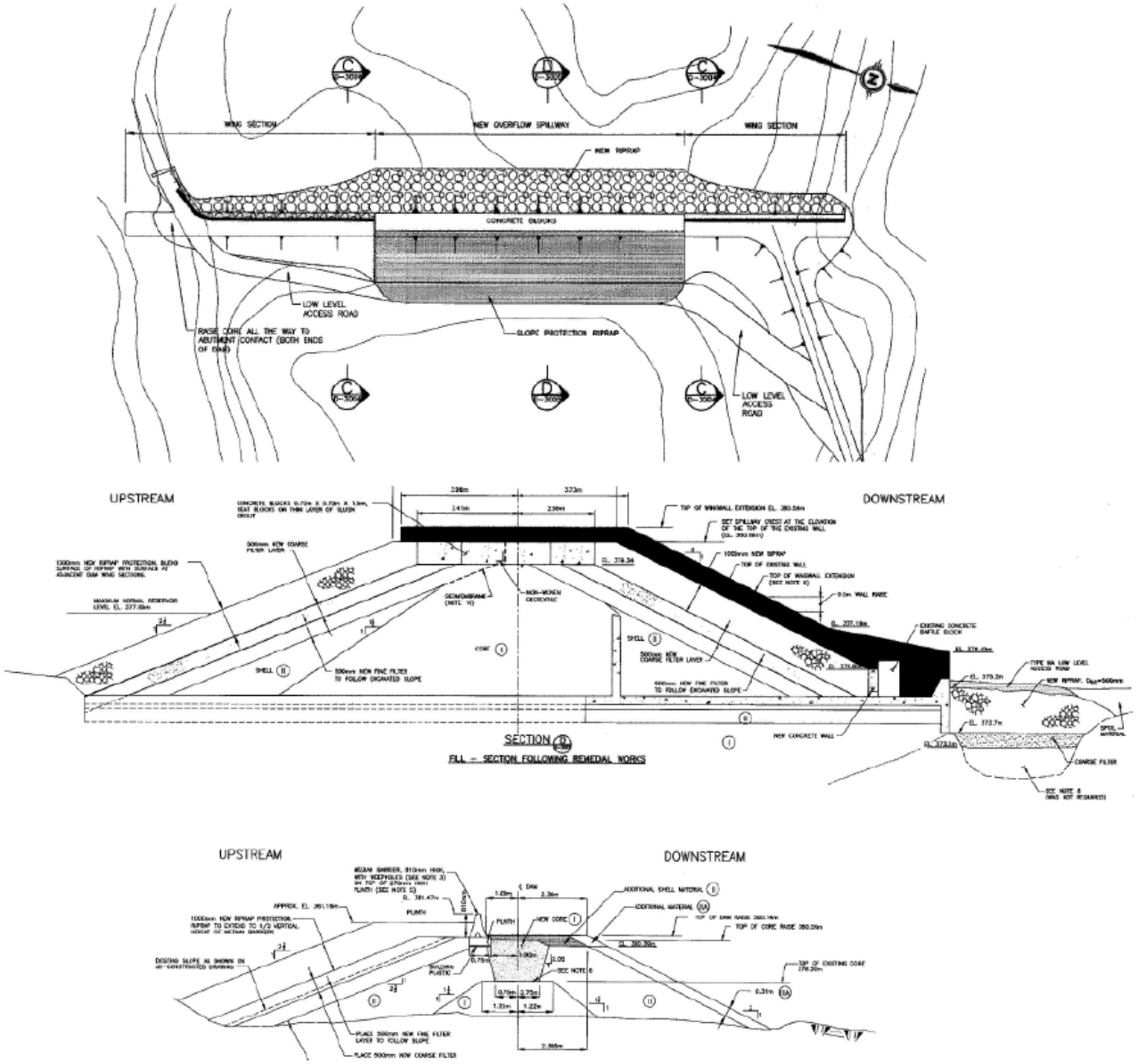
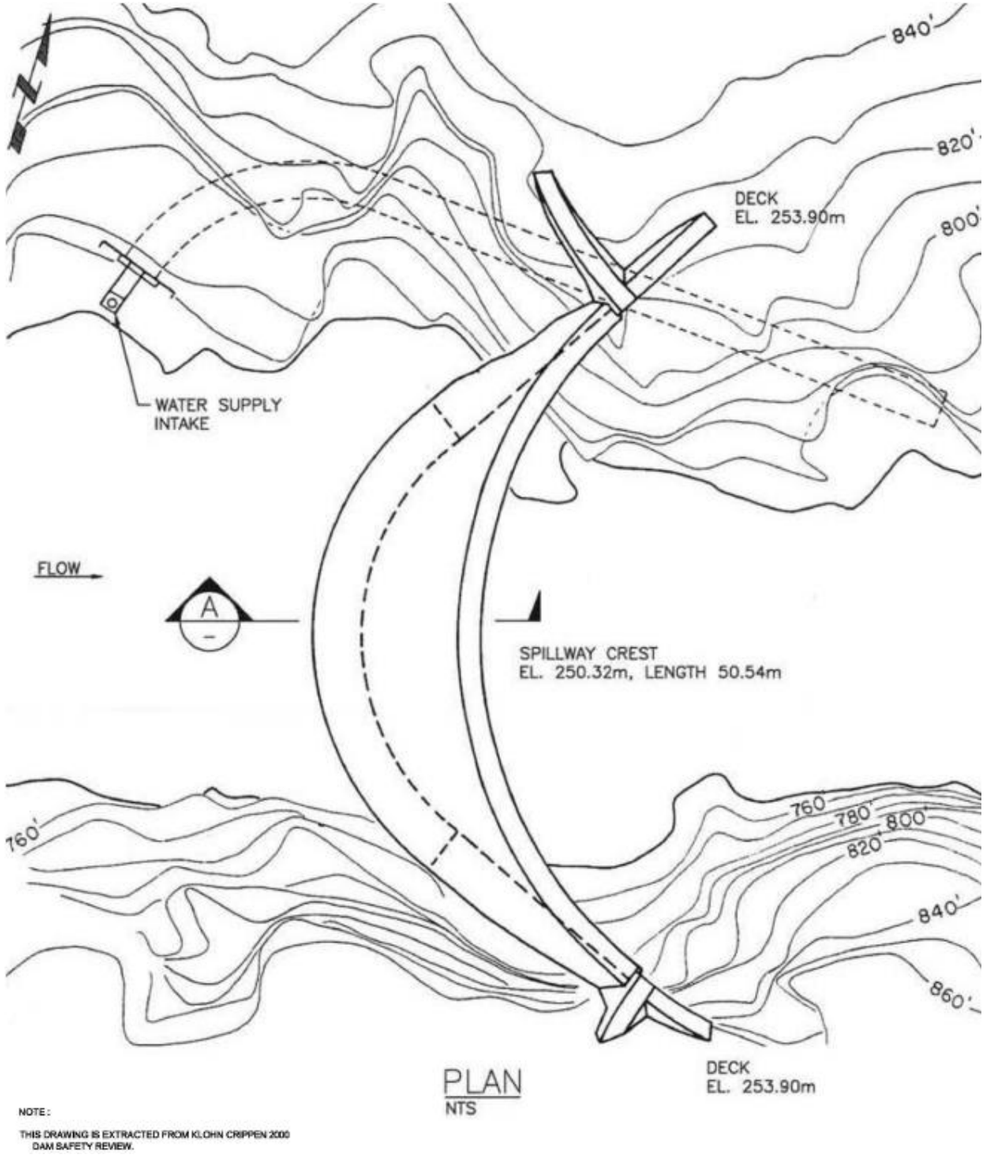



**Figure B3: General Layout of the Auxiliary Jump Creek Dam (Figure taken from 2016 FAD)**



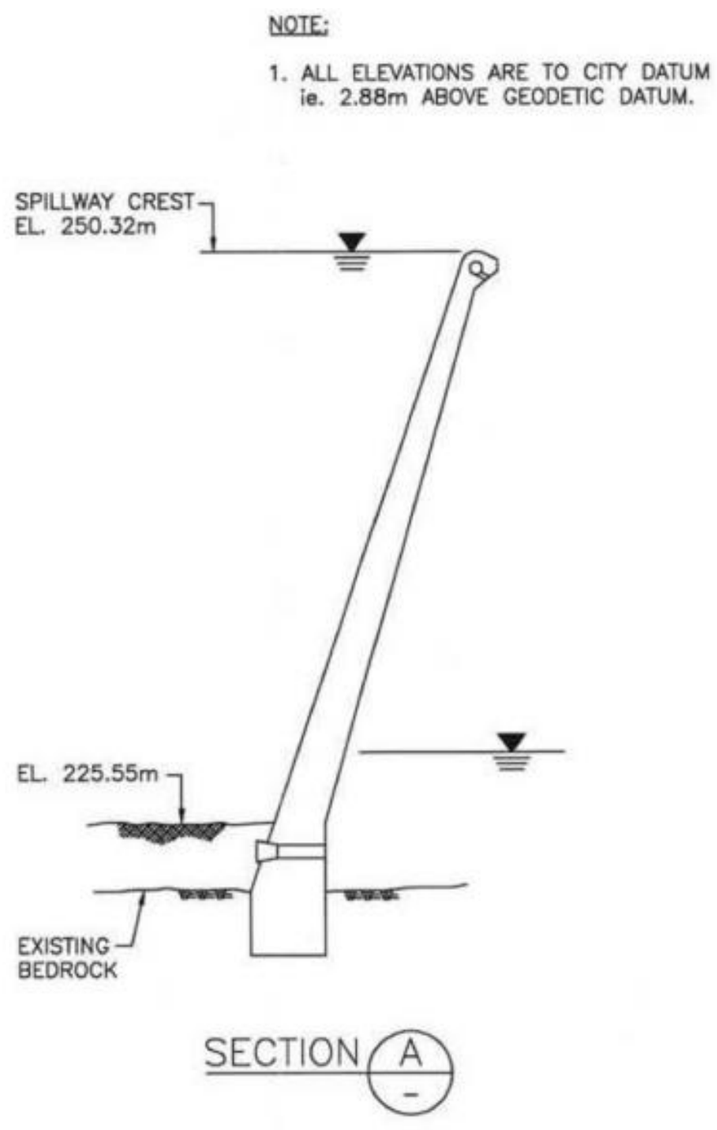




**Figure B4: General Layout of the South Dam (Figure taken from 2014 DSR)**

# Appendix C
# Inspection Photographs

**JCR 1: Upstream Face of the Dam, with Smaller Size Rock Particles along the Reservoir**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 2: Log Boom at Right Anchors**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 3: Log Boom Left Anchor**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 4: Downstream Side of Spillway Concrete Structure**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 5: Upstream Side of Spillway Structure**

Location: Jump Creek Dam (JCR)

Date: September 26. 2023

**JCR 6: LLO Intake Gate at Upstream Face**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 7: Steel Grating and Angles on Spillway Deck to Prevent Wheel Loading on Grating**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 8: Spillway Gate Operating Area**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 9: Spillway Chute (looking Upstream)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 10: Vegetation near to Right Wall of Spillway Chute**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 11: Open Spillway gates**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 12: Spillway Structure Chute (looking Downstream)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 13: Small Debris Inside Spillway Structure Chute (Looking Downstream)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 14: Construction Joints in Spillway Structure Chute**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 15: Spillway Structure Chute**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 16: Upstream Face of Dam with Log Boom**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 17: Dam Crest (Looking towards the Left Abutment)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 18: LLO Intake at the Upstream Face of the Dam**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 19: Reservoir and Boom (from Right Abutment)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 20: Downstream Side of LLO**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 21: LLO Concrete Structure at Downstream Side (Right Wingwall)**

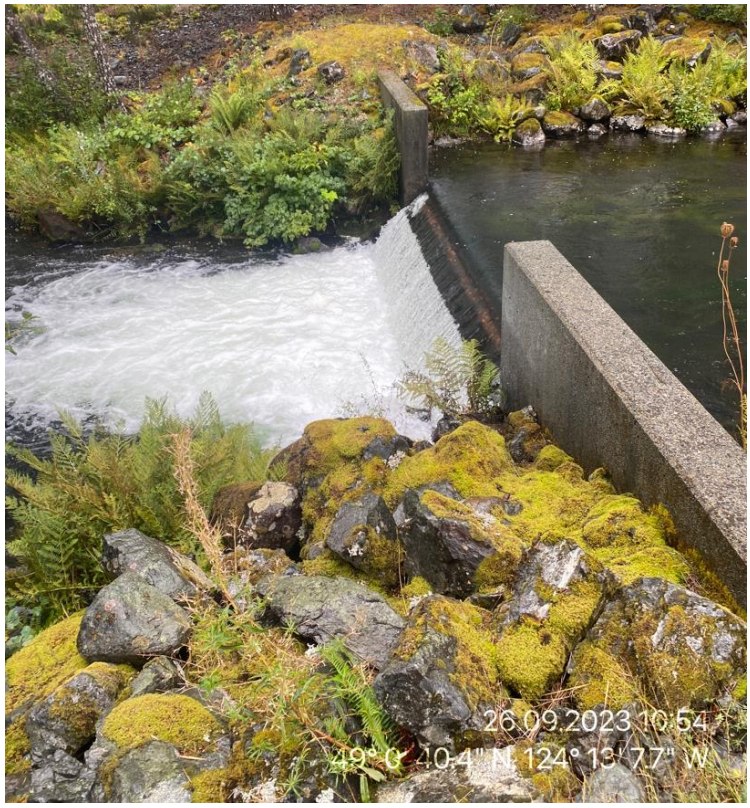
Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 22: Water level downstream of the LLO**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023




**JCR 23: LLO Channel and Downstream Concrete Weir**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 24: LLO Channel and Downstream Concrete Weir (Looking Downstream)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 25: Typical Standpipe Piezometer Casing (SP 3 b)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 26: Typical Standpipe Piezometer within Casing (SP 3 b)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 27: Flowing Water at Weir A**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 28: Flowing Water at Weir B**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 29: Light Water Flow at Weir C**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 30: Flowing Water at Weir D**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 31: Flowing Water at Weir E**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 32: Sign of Seepage on Downstream Face Near the Right Abutment**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 33: Previously Observed Wet Spot on the Lower Access Road Upstream of Weir E**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 34: Good Condition Riprap with Average Interlock Observed on Upstream Face of Dam (Looking towards the Right Abutment)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 35: Poor Quality Riprap Left of Piezometer SP12**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 36: Downstream Right Abutment**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 37: Bulge on Downstream Face (Looking from Downstream Toe)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 38: Downstream Toe with Ruts and Seepage**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 39: Over-steepened Section in the Upstream Riprap at the left Abutment**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 40: Auxiliary Spillway with Concrete Block Crest and Upstream Face of Dam (Looking towards the Right Abutment)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 41: Auxiliary Spillway and Downstream Face of Dam (Looking towards the Left Abutment)**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 42: Auxiliary Spillway and Downstream Face of Dam, zone with sparse riprap**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 43: Auxiliary Spillway and Downstream Face of Dam, zone with sparse riprap**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**JCR 44: Seepage at Downstream Toe of Auxiliary Spillway**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023


**JCR 45: Auxiliary Crest Concrete Block**

Location: Jump Creek Dam (JCR)

Date: September 26, 2023

**SFK 1: South Fork Dam Reservoir**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 2: South Fork Dam (looking from Left Abutment)**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 3: Shotcrete at the Entry to Water Supply Tunnel**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 4: Water Supply Intake Debris Boom**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 5: Right Abutment Rockface**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 6: Left and Right Concrete Abutments**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 7: Downstream Face of Dam**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 8: Upstream Face of Intake Tunnel**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 9: Water Supply Pipe Anchor and Foundation Block**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 10: Tunnel Weir Seepage**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 11: Headwall Shotcrete Condition (Downstream)**

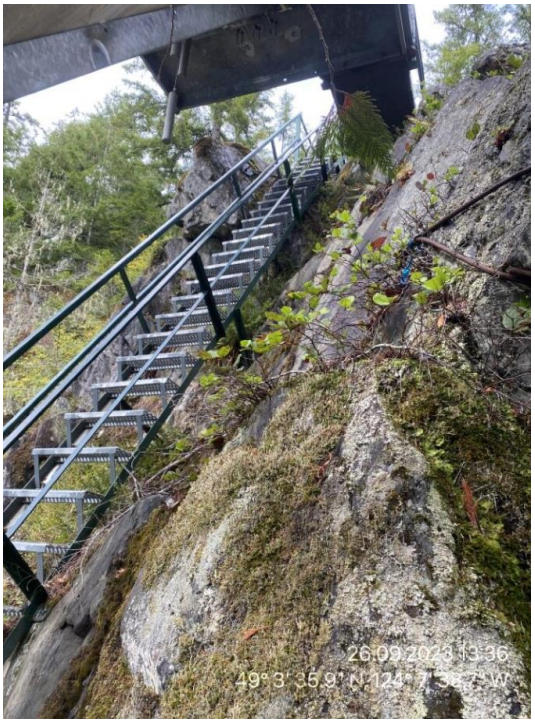
Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 12: Rock Slope with Rock Bolts and Mesh Installed Behind Building**

Location: South Fork Dam (SFK)

Date: September 26, 2023




**SFK 13: Exposed Bedrock Upstream of Left Abutment**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 14: Potential Rock Block Instability Located Upstream of Left Abutment**

Location: South Fork Dam (SFK)

Date: September 26, 2023

**SFK 15: Loose Rocks Observed at the Toe of the Left Wall of the Supply Tunnel, where Local Shear Clay-filled Discontinuity is Found**

Location: South Fork Dam (SFK)

Date: September 26, 2023

# Appendix D
# City of Nanaimo – Mobile Dam Inspection Database September 2023

**City of Nanaimo Dam Inspection Database – Week Ending September 8, 2023**

Hatch undertook formal annual dam safety inspections of the City's water supply and recreational dams from September 26 to 28, 2023.

The readings of each dam from the City's dam inspectors at the closest inspection date prior to the Hatch inspection (note this inspection was 2 weeks prior to the Hatch inspection). Dam Inspector comments are included at the end of each dam inspection report.

**Jump Creek Dam - Page 1**

| | | | |
|---|---|---|---|
| **Inspected By:** | B Martin | **Reservoir Level:** | -204 cm |
| **Date:** | 08-Sep-23 | | |
| **Weather:** | Sun | | |
| **Ground Condition:** | Dry | | |

**Weekly Inspection Checklist**

| Feature | Concern | Rating | Comments |
|---|---|---|---|
| Reservoir | Debris | Moderate | Add |
| Log Boom | South Anchor | Satisfactory | Add |
| | North Anchor | Satisfactory | Add |
| | Chain and Cable | Deficient | Add |
| | Logs | Satisfactory | Add |
| Dam Crest | Cracking | N/A | Add |
| | Erosion | Minor | Add |
| | Settlement | Minor | Add |
| Upstream Slope | Debris | Moderate | View |
| | Erosion | Minor | Add |
| | Settlement | Minor | Add |
| | Vegetation Growth | Minor | Add |
| Downstream Slope | Erosion | Minor | Add |
| | Seepage | Minor | Add |
| | Settlement | Minor | Add |
| | Vegetation Growth | Moderate | View |
| Spillway | Cracking | Minor | Add |
| | Debris | Minor | Add |
| | Movement | N/A | Add |
| | Spalling | Minor | Add |

| Spillway Bridge and Gate Controls | | | |
|---|---|---|---|
| #1 Gate Structure | Condition | Satisfactory | Add |
| #2 Gate Structure | Condition | Satisfactory | Add |
| #1 Gate Cables and Sheave Assembly | Condition | Satisfactory | Add |
| #2 Gate Cables and Sheave Assembly | Condition | Satisfactory | Add |
| #1 Gate Seals | Condition | Satisfactory | Add |
| #2 Gate Seals | Condition | Satisfactory | Add |
| Paint Work | Condition | Satisfactory | Add |
| Hand Rails | Condition | Satisfactory | Add |

| Gate Controls - Building | | | |
|---|---|---|---|
| Gate Electrical Controls | Condition | Satisfactory | Add |
| #1 Diesel Generator | Condition | Satisfactory | Add |
| #2 Diesel Generator | Condition | Satisfactory | Add |
| Generator Maintenance/Testing | Completed | Yes | Add |

| Low-Level Outlet | | | |
|---|---|---|---|
| Gear Operator | Condition | Satisfactory | Add |
| Gate Stem and Guides | Condition | N/A | Add |
| Gate Operation | Condition | Satisfactory | Add |
| Tunnel | Condition | Satisfactory | Add |
| Energy Dissipator | Condition | Satisfactory | Add |
| Rectangular Weir | Condition | Satisfactory | Add |

| Auxiliary Dam/Overflow Spillway | | | |
|---|---|---|---|
| Auxiliary Dam/Spillway | Debris | Moderate | View |
| | Vegetation Growth | Minor | Add |
| Upstream Slope and Groin | Condition | Satisfactory | Add |
| Downstream Slope and Groin | Condition | Satisfactory | Add |
| Downstream Toe and Roadway | Condition | Satisfactory | Add |
| Lock Block Crest | Condition | Satisfactory | Add |
| | Photo taken | No | Add |
| Ground Survey | Completed | No | Add |

## South Fork Dam

| | | | |
|---|---|---|---|
| **Inspected By:** | B Martin | **Reservoir Level:** | -2 cm |
| **Date:** | 08-Sep-23 | **Weir Level:** | cm |
| **Weather:** | Sun | | |
| **Ground Condition:** | Dry | | |
| **Crack Gauge #1:** | | | mm |
| **Crack Gauge #2:** | | | mm |

### Weekly Inspection Checklist

| Feature | Concern | Rating | Comments |
|---|---|---|---|
| Reservoir | Debris | Minor | Add |
| Control Platform | Condition | Satisfactory | Add |
| Embankment Rip Rap | Condition | Satisfactory | Add |
| Fisheries Outlets and Valving | Condition | Satisfactory | Add |
| Valve Chamber | Condition | Satisfactory | Add |
| Weir at Tunnel | Condition | Unsatisfactory | Add |

### Monthly Inspection Checklist

| | | | |
|---|---|---|---|
| Above Water Inlet Structure | Condition | Satisfactory | Add |
| Left Abutment | Condition | Satisfactory | Add |
| Retaining Wall (Next to Intake) | Condition | Satisfactory | Add |
| Right Abutment | Condition | Satisfactory | Add |
| Tunnel and Piping | | | |
| Entrance, Shotcrete Face Condition | | N/A | Add |
| Rock Walls and Ceiling Condition | | N/A | Add |
| Pipe Condition (Staining, Coating) | | N/A | Add |
| Debris | | Minor | Add |
| Log Boom | South Anchor | N/A | Add |
| | North Anchor | N/A | Add |
| | Chain and Cable | N/A | Add |
| | Logs | N/A | Add |

**Yearly Inspection Checklist**

| | | | |
|---|---|---|---|
| 48" Supply Inlet | Condition | N/A | Add |
| Downstream Face | Condition | N/A | Add |
| Drain Plug Center | Condition | N/A | Add |
| Drain Plug Left | Condition | N/A | Add |
| Roads | Sloughing | N/A | Add |
| Culvert Condition (Erosion) | | N/A | Add |
| Inlet Chlorine Packs | Added | Yes | Add |
| Ground Survey | Completed | No | Add |

**Jump Creek/South Fork Piezometers/Weir Levels**

New Record | View Existing | Select Date: 9/8/2023

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Date: | 08-Sep-23 | SP7b (m): | 12.50 | SP12-3 (m): | 4.97 | Frozen | Weather: | Sun |
| Gate Level (ft): | 08'00" | SP9 (m): | 9.96 | Weir A (cm): | 1.70 | ☐ | Precipitation (mm): | 0.00 |
| JC Lake Level (m): | -2.04 | SP10-1 (m): | 10.72 | Weir B (cm): | 0.00 | ☐ | Discharge Gate CFS: | 30.00 |
| SP1b (m): | 9.81 | SP10-2 (m): | 10.62 | Weir C (cm): | 0.00 | ☐ | Air Temp (c): | 14.00 |
| SP2b (m): | 10.87 | SP11 (m): | 10.11 | Weir D (cm): | 0.00 | ☐ | Fisheries Valve (L/s): | 281.80 |
| SP3b (m): | | SP12-1 (m): | 12.75 | Weir E (cm): | 0.00 | ☐ | SF Lake Level (m): | -0.02 |
| SP4b (m): | 9.71 | SP12-2 (m): | 10.71 | | | | | |

Submit | Cancel

| INSP_DATE | GATE_LEVEL | JC_LAKE_LEVEL | SP1b | SP2b | SP3b | SP4b | SP7b | SP9 | SP10-1 | SP10-2 | SP11 | SP12-1 | SP12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08-Sep-23 | 00" | -2.04 | 9.81 | 10.87 | Null | 9.71 | 12.50 | 9.96 | 10.72 | 10.62 | 10.11 | 12.75 | 10.71 |
| 04-Oct-23 | 00'00" | -2.98 | 10.01 | 10.84 | Null | 9.84 | 12.41 | 10.20 | 11.23 | 11.30 | 10.60 | 12.75 | 11.13 |
| 06-Oct-23 | 00'00" | -2.98 | 10.02 | 10.89 | Null | 9.85 | 12.45 | 10.21 | 11.42 | 11.36 | 10.63 | 12.80 | 11.15 |
| 13-Oct-23 | 00'00" | -3.00 | 9.93 | 10.75 | Null | 9.78 | 12.44 | 10.09 | 11.40 | 11.33 | 10.61 | 12.78 | 11.00 |
| 16-Oct-23 | 00'00" | -2.90 | 9.92 | 10.74 | Null | 9.68 | 12.17 | 10.14 | 11.44 | 11.36 | 10.56 | 12.67 | 10.94 |
| 20-Oct-23 | 00'00" | 0.37 | 9.09 | 9.48 | Null | 9.30 | 12.01 | 9.93 | 11.35 | 11.33 | 9.19 | 11.07 | 10.00 |
| 26-Oct-23 | 00'00" | 0.19 | 9.04 | 9.63 | Null | 9.06 | 12.01 | 10.31 | 10.89 | 10.85 | 8.89 | 11.06 | 9.48 |

Record: 1627 of 1638 | No Filter | Search