

7: Quarterly Dam Safety Report

Executive summary

The purpose of this report is to update the Operations, Planning, Information & Technology Committee of the Board of Directors on key dam risk management activities during the period from October 1 to December 31, 2022 (F2023 Q3) and to provide reasonable assurance that the safety of dams operated by BC Hydro continues to be managed to the established guidelines and criteria of the Dam Safety Program. To keep the Committee as fully abreast of the Dam Safety Program as possible, some notable developments that took place after December 31, 2022, but before the completion of this report have also been included.

The key highlights from F2023 Q3 and the beginning of Q4 documented in this report are:

















- The system's aggregated Vulnerability Index decreased by 12.1 through F2023 Q3, with spillway and low level outlet gates returned to service at Ruskin and Terzaghi Dams. See page 3.
- Following the rockfall from the Marble Shear Block at Revelstoke Dam, one lane of travel on the principal access road to the generating station was reopened with construction of a temporary protective berm, restoring access for safe delivery of essential equipment and materials to the station. See page 6.
- Final arguments for the John Hart Dam Seismic Upgrade Project have been submitted to the British Columbia Utilities Commission, in which Intervenors have generally recommended that the Commission determine that the project is in the public interest and approve the project expenditure schedule. See page 7.
- Updates to Operation, Maintenance and Surveillance Manuals for Comox Dam, Kootenay Canal and Stave Falls Dam were completed on schedule. See page 7.
- Civil maintenance on Dam Safety and Generation assets progressed well in F2023 Q3. Corrective and condition-based maintenance progressed fully to plan, and preventative maintenance exceeded quarterly targets to greatly improve year-to-date performance. See page 10.
- All spillway gate testing was performed according to plan and the maintenance status of the gates continued to improve. Through the first three quarters of F2023, there has been a 21 per cent decrease in outstanding maintenance tasks from 160 to 126. See pages 11-13.
- Release 1 of BC Hydro's next-generation information management system, the Dam Safety Information System, was placed into service. See pages 14-16.
- A successful meeting of the Dam Safety Advisory Board for the three Campbell River System upgrade projects was held, out of which the Advisory Board has confirmed their overall endorsement of the design work and planning that has been performed to date and their opinion that the projects are on track to fully meet the projects' objectives. The Advisory Board further identified aspects of the projects that "set a standard above other hydropower companies..." See page 18.
- New projects were initiated at Hugh Keenleyside Dam to mitigate potential fish stranding, at Mica Dam to upgrade intake gate hydraulic systems, at Revelstoke Dam to provide adequate monitoring / stabilization measures on the Marble Shear Block, at Terzaghi Dam to address seismic performance deficiencies, and at various sites to replace reservoir booms. See pages 19-21.

Presenter: Bob Schubak (Director, Dam Safety)

7: Quarterly Dam Safety Report

Dam Safety Program Dashboard

The following dashboard provides an overview of the status of the Dam Safety Program. “Traffic lights” provide a qualitative indication of the status of each of five elements of the Program and trend arrows identify whether the status is improving, deteriorating or unchanged. As referenced, these indicators are supported by more detailed metrics and narratives in the report.

Risk Profile and Issues Management	 	<ul style="list-style-type: none">• Vulnerability Index (pp. 3-5): The aggregated Vulnerability Index was reduced by 12.1 (approximately five percent) through Q3.• Program Non-Conformances (p. 5): The total number of non-conformances was reduced by 14 (approximately four percent) through Q3.• New and Current Issues (p. 6): No new issues arose in Q3 and issues from last quarter pertaining to white sturgeon entering the low level outlets at Hugh Keenleyside Dam and the rockfall at Revelstoke Dam are under active management.
Regulatory Compliance	 	<ul style="list-style-type: none">• Operation, Maintenance and Surveillance Manual Updates (p. 7): Work continued to plan on scheduled Manual updates. Three updates were completed in Q3.• Dam Safety Reviews (p. 7): Dam Safety Reviews that were scheduled for completion in F2022 but were held in draft for improvements before issuing will be completed in Q4. F2023 Reviews are progressing on schedule.
Surveillance	 	<ul style="list-style-type: none">• Dam Inspections (pp. 8-9): 410 of 411 scheduled routine dam inspections were completed in Q3. Formal dam inspections were caught up in Q3.• Reservoir Slopes (p. 9): Field work for reservoir slopes inspections was completed in Q3. Reporting lagged slightly resulting from the required response to the Marble Shear rockfall in October.
Maintenance and Testing	 	<ul style="list-style-type: none">• Civil Maintenance (p. 10): Condition-based and preventative civil maintenance progressed well in Q3.• Spillway Gates (pp. 11-13): All 238 scheduled gate tests were completed. One gate failed to operate on demand. The number of outstanding maintenance tasks decreased by 17 over Q3.
Projects and Investigations	 	<ul style="list-style-type: none">• Capital Projects (pp. 17-20): The Advisory Board meeting for the Campbell River System projects was successfully completed. Installation of piezometers on Cheakamus Dam was completed ahead of schedule. The La Joie Dam Improvements project advanced to Feasibility Design stage. Four new projects were initiated.• Dam Safety Investigations (p. 20): No notable updates.
Legend:	     	<p>All areas within the Program element are being implemented to a satisfactory level. Minor, isolated issues may exist but are not deemed to be indicative of deteriorating performance.</p> <p>One or more areas within the Program element exhibit or are at risk of underperformance and are being monitored.</p> <p>One or more areas within the Program element exhibit unsatisfactory performance and require correction.</p> <p>Status of the Program element has improved over the quarter.</p> <p>Status of the Program element was unchanged over the quarter.</p> <p>Status of the Program element deteriorated over the quarter.</p>

7: Quarterly Dam Safety Report

Risk Profile of BC Hydro's Dams

Dam Safety Contribution to Enterprise Risk

Dam Safety is assigned a high “risk priority” within BC Hydro’s Enterprise Risk report. Please refer to that report for additional details.

Vulnerability Index Update

Identified physical deficiencies in BC Hydro’s dams and the degree of concern that exists with respect to their impact on the integrity and performance of the dam are characterized by the Vulnerability Index. The higher the value of the Vulnerability Index (scale of 0-10), the higher the likelihood of that deficiency leading to poor performance. The Vulnerability Index for each identified issue at each dam site is shown in Figure 1. Vulnerability Indices for the individual deficiencies are aggregated into stacked bars for each dam, and dams are sequenced from left to right in order of increasing downstream consequences per the BC Dam Safety Regulation. Changes in Vulnerability Index for actual and potential deficiencies (including those related to spillway reliability), aggregated across the entire fleet of dams, are tracked on a quarterly basis and shown in Figure 2.

Notable changes in Vulnerability Index in F2023 Q3 are identified in Figure 1 and described below.

- 1** An **addition** of 0.7 (Actual Unusual deficiency) at **Elsie Dam**.
The crest elevation of Saddle Dam 3 is 0.5 metre lower than the design elevation at some locations. The design freeboard above the Probable Maximum Flood level (without wind effects) is 0.68 metre and the freeboard at the lowest surveyed crest elevation is 0.20 metre. Further investigation is required to study the risk and the potential repair measures.
- 2** A **reduction** of 1.0 (Potential Normal deficiency) at **Hugh Keenleyside Dam**.
In response to concerns that the reverse filter berm at the downstream right abutment of the earthfill dam might not be functioning as intended, an investigation was undertaken to review the design, construction and performance of the berm. Based on the investigation’s findings, the Dam Safety Engineer’s considers that the berm is currently functioning as intended and the issue has been closed.
- 3** A **reduction** of 5.9 (Spillway Reliability deficiency) at **Ruskin Dam**.
The F2022 Q4 report described that a significant oil leak was discovered and was traced back to one of the two hydraulic cylinders on Spillway Gate 3. The gate was returned to service in F2023 Q1 following the replacement of the damaged hydraulic cylinder. Documentation for the closure of this deficiency was issued in Q3.
- 4** A **reduction** of 5.9 (Spillway Reliability deficiency) at **Terzaghi Dam**.
The F2022 Q4 report described that Low-Level Outlet Gate 1 was unable to open freely, achieving only limited openings, and put into restricted service. In F2023 Q1, an oil change and oil system flush were completed. The gate was returned to full service and has been successfully operated since that time. Documentation for the closure of this deficiency was issued in Q3.

7: Quarterly Dam Safety Report

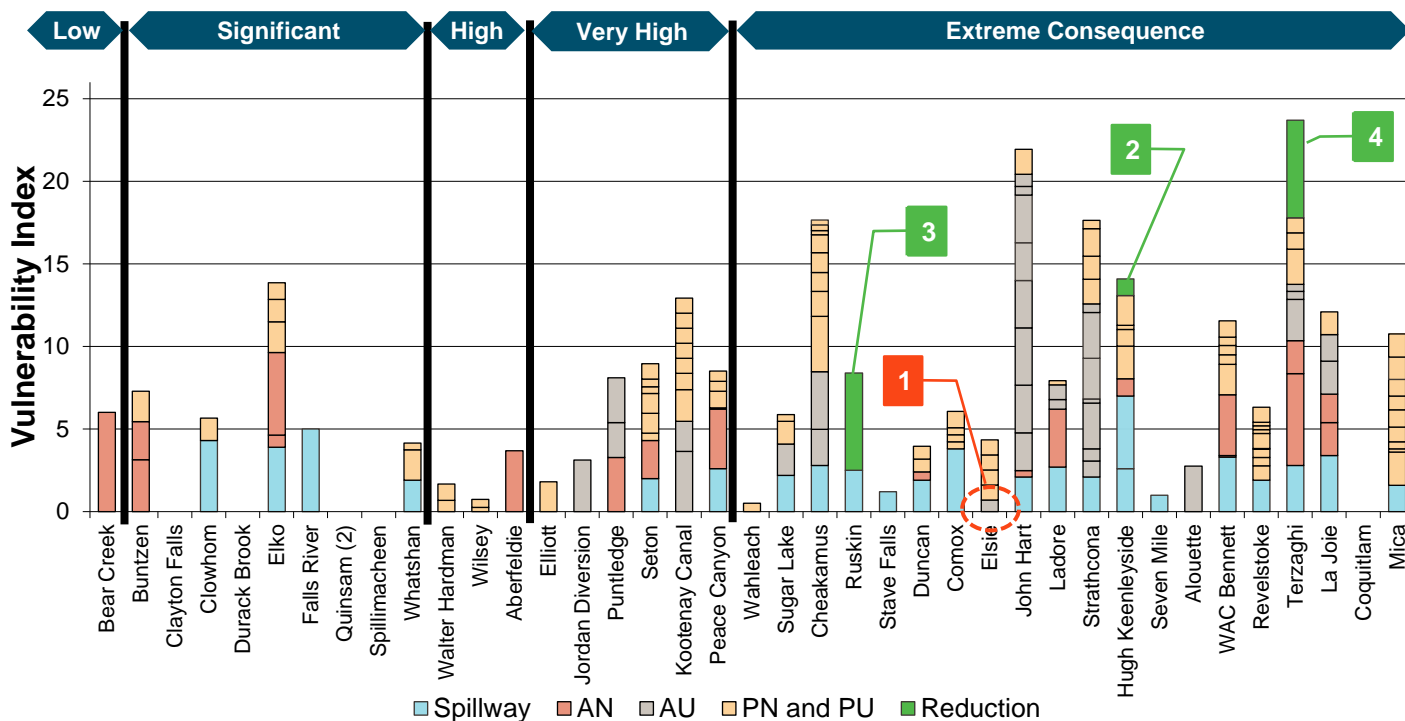


Figure 1 Dam Safety overall risk profile at the end of F2023 Q3, as represented by the Vulnerability Index. Changes this quarter are indicated by the numbered boxes.

- AN** Actual deficiency (demonstrated to exist) under *normal* load conditions
- AU** Actual deficiency (demonstrated to exist) under *unusual* load conditions
- PN and PU** Potential deficiency (requiring further investigation to demonstrate existence) under either normal or unusual conditions
- Spillway Reliability** Actual or potential deficiency related to operational reliability of the dam's spillway and/or other flood discharge systems

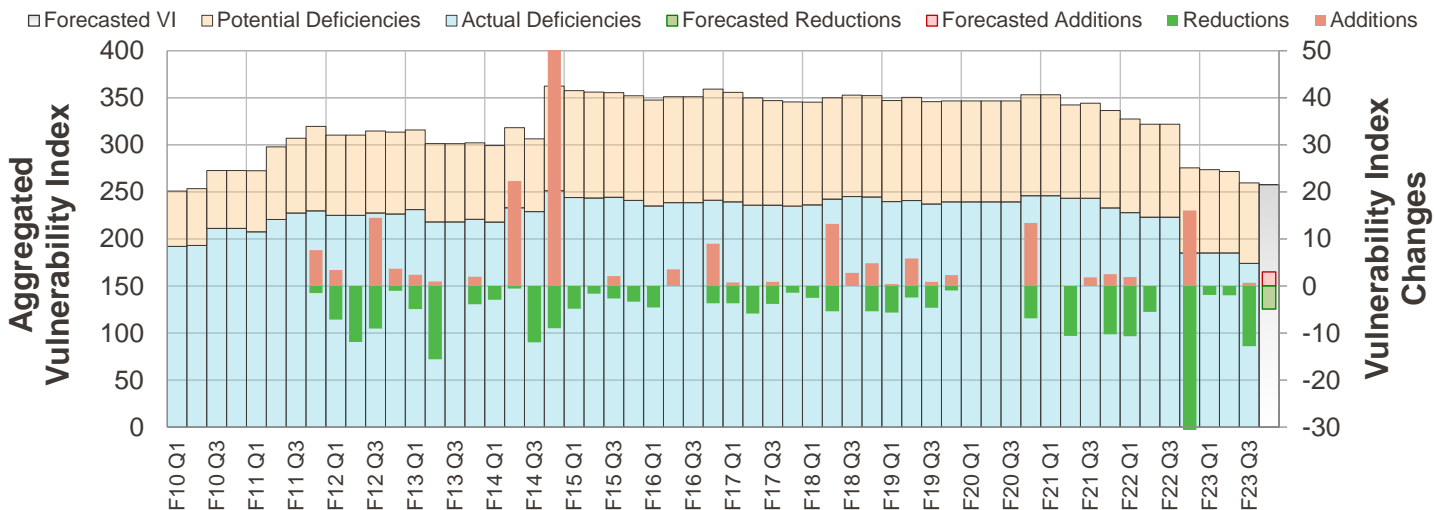


Figure 2 Historical and forecast changes and trends in the Vulnerability Index aggregated across the BC Hydro system.

7: Quarterly Dam Safety Report

Over the last several years, new issues have added to the aggregated Vulnerability Index at a rate of approximately 12 per annum. To prevent deterioration of the overall risk position, reductions in Vulnerability Index through resolved issues should occur at the same pace or faster. Table 1 below confirms that this is presently the case; that Vulnerability Index reductions have far exceeded additions over the past four quarters and that forecast Vulnerability Index reductions through F2023 will exceed the target.

Table 1 Trends and forecasts for Vulnerability Index changes in F2023.

		Actual / Forecast	Target
Dam Safety Vulnerability Index	Reductions - Last 4 quarters	79.0	12 ✓
	Forecast Reductions – Fiscal Year	21.6	12 ✓
	Additions - Last 4 quarters	16.8	

Non-Conformances in the Dam Safety Program

Activities to identify, review, resolve and close Non-Conformance issues continued through F2023 Q3. As a result, 22 Non-Conformance issues were completed and eight new issues were identified.

There are currently 362 outstanding Non-Conformance issues in the database, which is 21 less than at the start of F2023. Since the start of F2019, when resolution of such issues was made a priority within the Dam Safety Program, the number of Non-Conformance issues has been reduced by approximately 35 percent. Figure 3 below shows the continuing progress in reducing the number of Non-Conformance issues.

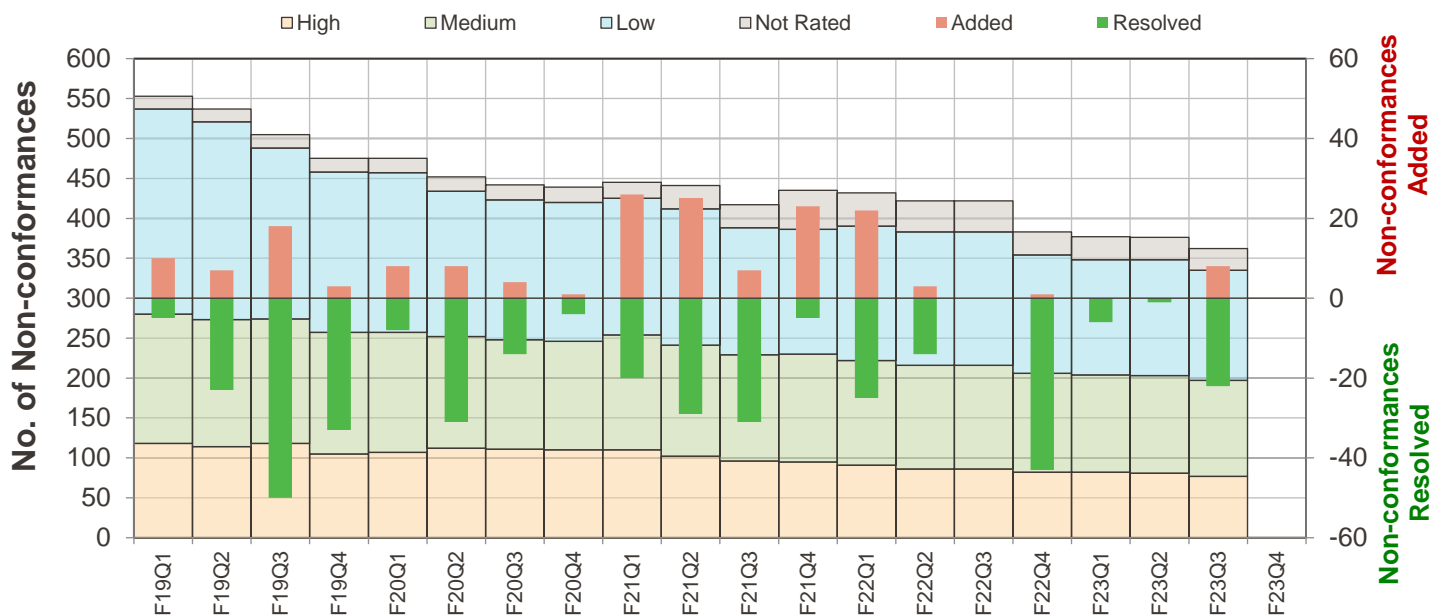


Figure 3 Changes and trends in the total number of Non-Conformance issues (characterized by level of importance) within the Dam Safety Program.

7: Quarterly Dam Safety Report

New Issues

No new issues arose in F2023 Q3.

Update on Existing Issues

Revelstoke Dam – Rockfall on Marble Shear Block

As reported last quarter, approximately 350 cubic metres of rock fell from the feature known as the Marble Shear Block into the main parking lot at Revelstoke Generating Station occurred at approximately 2:00 am on the morning of October 5, 2022. Following the rockfall, monitoring through daily point cloud laser surveys, drone surveys, and inspections of the slopes above for signs of potential progressive failure was established and continued as weather and conditions permitted, from which no additional slope movements or signs of progressive failure were observed.

A temporary protective berm, composed of lock blocks and rock and designed to contain a similar rockfall, was constructed along the centerline of the road below and completed in mid-November, allowing one lane of the access road to be opened up for safe delivery of essential equipment and materials to the station. See Figure 4 at right.

A new capital project was released in Q3 to design and implement permanent stabilization of the rock slope and reporting will be provided in the Capital Projects section of this and future reports.

Hugh Keenleyside Dam – White Sturgeon in Low Level Outlets

As reported last quarter, white sturgeon, an Endangered Species under the Federal Species at Risk Act, have been entering the dam's low level outlet ports and swimming up the operating gate slots to access the tops of the gates. If the low level outlet port's gate were opened, either for operational water conveyance or monthly gate testing, the fish would be subjected to considerable water turbulence and vulnerable to injury or mortality. BC Hydro is continuing to monitor for the presence of white sturgeon before any operation or testing of the gates. We are communicating with the Department of Fisheries and Oceans to develop longer term solutions and an application for a permit to test an operational procedure with sturgeon present has been submitted to that agency. Engineering solutions to exclude sturgeon from the gate slots are also being investigated. Further updates will be provided in future reports.

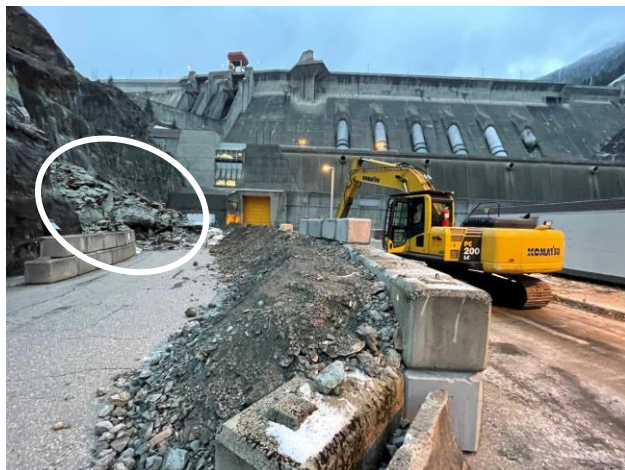


Figure 4 Construction of the temporary rockfall protection berm on the access road beneath the Marble Shear Block at Revelstoke Dam. The October 5 rockfall is circled for reference.

7: Quarterly Dam Safety Report

Compliance with Processes and Regulations

Regulatory Communications – British Columbia Utilities Commission

The application to the British Columbia Utilities Commission for the John Hart Dam Seismic Upgrade Project continued through F2023 Q3 and into Q4. The third round of Information Requests pertaining to the updated costs was completed. BC Hydro's Final Argument was submitted on January 12, 2023, and Interveners' Final Arguments were received on January 25, 2023. Interveners generally indicated their support for the project need, alternative selected, project scope and cost estimate, and recommended that the Commission determine that the project is in the public interest and approve the project expenditure schedule.

Regulatory Communications – Comptroller of Water Rights

Regulatory Communications with the Provincial Dam Safety Office in F2023 Q3 consisted of two submissions related to the John Hart Seismic Upgrade Project: firstly, the request for dam alteration authorization for the upgrade, which was approved subject to the condition of the water licenses which require BC Hydro to hire an Independent Engineer and to obtain Leave to Commence Construction for each phase of the work; and secondly, a request for approval of invasive investigations on the dam to inform the project's detailed design, which was also approved.

The 2023 annual meeting between Dam Safety and the office of the Comptroller of Water Rights was held on January 23 and 25 with one day dedicated to updates on the capital projects and the second day focused on the Dam Safety Program.

Operation, Maintenance and Surveillance Manuals

Each dam has an Operation, Maintenance and Surveillance Manual ("Manual") for Dam Safety that identifies responsibilities and expectations within BC Hydro for maintaining the safety of the dam. These Manuals are required by the Dam Safety Regulation and must be updated every seven to ten years, depending upon the dam's failure consequences classification.

Work on updates to these Manuals kept to plan through F2023 Q3, with three Manuals – for Comox Dam, Kootenay Canal and Stave Falls Dam – having been completed. Manuals for Cheakamus Dam and Ruskin Dam are scheduled to be issued in Q4 and are also progressing to plan.

Dam Safety Reviews

Dam Safety Reviews are independent, systematic reviews and evaluations of all aspects of a dam's physical condition, design, construction, operation, maintenance, processes, and other systems affecting the safety of the dam. Performed by external consultants, they are carried out at minimum intervals of every five to ten years for dams that are classified in accordance with the Dam Safety Regulation as High, Very High, and Extreme consequence dams.

As of the end of Q3, the Dam Safety Review of Wahleach Dam had been completed, and three Dam Safety Reviews (Terzaghi Dam, La Joie Dam, Seton Dam) that were scheduled for completion in F2022 remained in progress, requiring additional revisions prior to being issued. Since the end of Q3, progress on these reports is such that they are all expected to be completed and issued in Q4.

The Dam Safety Review of Elsie Dam has progressed well through F2023 and is on track to be issued in Q4. The Ruskin Dam Safety Review was begun in Q3 and will be finalized in Q1 of F2024.

7: Quarterly Dam Safety Report

Surveillance

Key activities comprising dam safety surveillance include inspections, monitoring of instrumentation and quality control of data, and characterization of dam performance. Table 2 below provides key metrics regarding these activities, which are described in the following sub-sections of the report.

Table 2 Dam safety inspections and surveillance activities.

		Quarter Q3		Year-To-Date	
		Actual	Target	Actual	Target
Routine dam inspections	Completed	410/411 = 99.8%	100%	1231/1233 = 99.9%	99.5% ✓
	Missed	1		1	
Formal (annual and semi-annual) dam inspections	Field work completed	27	16	71	71 ✓
	Reports issued	16	21	22	31 ✗
Instrumentation data checks		197/195 = 101%	95%	593/585 = 101%	95% ✓
Reservoir slopes inspections	Field work completed	3	4	20	20 ✓
	Reports issued	1	8	8	12 ✗

Routine Dam Inspections

Routine weekly and monthly inspections are a regulatory requirement. These visual inspections are carried out by trained inspectors within Dam Safety or Stations Field Operations using checklists prepared by the Dam Safety Engineer. The purpose of these inspections is to identify changing conditions at a dam, reservoir or appurtenant structure that could threaten the safety of the dam.

In Q3, 410 of the 411 scheduled site inspections were completed. The single missed inspection – the first miss out of more than 1200 scheduled inspections in F2023 – occurred after the heavy snowfall in December, during which period the access road to Alouette Dam was uncleared and could not be traveled. Stations Field Operations canceled this inspection with Dam Safety's agreement.

Formal Dam Inspections

Formal inspections of the dams are regulatory inspections completed by Dam Safety Engineers on a semi-annual or annual frequency, as dictated by each dam's Consequence Classification. These inspections include a comprehensive visual inspection, a review of the monitoring data and an assessment of the condition of the water containment and conveyance structures. The Dam Safety Engineers are required to complete 71 of these inspections and reports annually.

As of the end of Q3, the field work for all 71 inspections had been completed. While only 22 inspection reports had been issued, lagging the planned completion of 31 reports, an additional nine reports were essentially complete and in the

7: Quarterly Dam Safety Report

process of final formatting prior to issuing. These nine reports – and others – have since been issued and formal dam inspections are back on track with the F2023 plan.

Instrumentation and Monitoring

Dam Safety Surveillance collects, checks, and assesses about two million data points a month. A vast majority of the data is collected and checked against threshold values automatically by the Automated Data Acquisition System. Even though most of the data is checked automatically it is essential that qualified staff review the data regularly to ensure the systems are functioning as expected. The Dam Safety Technologists in each region regularly check instrumentation data plots for all dams to ensure the Automated Data Acquisition System is functioning as expected, identify any unusual trends, and ensure continued accuracy of the data being for ongoing engineering assessment. They are tasked to perform three such checks per week. 197 of these checks were completed in Q3, which is slightly above the target of 195.

Reservoir Slopes

Reservoir Slopes inspections are completed on a frequency ranging from semi-annually to once every 10 years depending on the assessed hazard of the slope. They are typically carried out by the Reservoir Slopes Geologist and the Specialist Dam Safety Engineer for the Upper Columbia Region. The inspections generally consist of a review of all monitoring data and a visual inspection completed from helicopter with boots-on-ground assessment of identified areas of concern.

As of the end of Q3, the field work for all twenty planned slopes inspections in F2023 had been completed. No new issues have been identified through these inspections. Only eight engineering reports documenting the performance of the slopes had been issued against a plan of twelve, however, with the attention of our slope specialists being focused on the Marble Shear rockfall (page 6). Two more reports were issued in early January, and the remaining ten reports will be completed prior to the end of the fiscal year.

Dam Safety is continuing to advance the use of satellite-acquired remote sensing (Interferometric Synthetic Aperture Radar, or “InSAR”) data for landslide detection and monitoring along our reservoirs. Newly monitored areas using this technology were the northern end of the Upper Arrow Lake reservoir and the Santa Claus Mountain and Wedge Drop Mountain landslides in the Bridge River system, where no new concerns have been identified. Monitoring of the St. Cyr landslide also continued in F2023, where landslide displacement rates remain consistent with previously reported results.

Unusual Events or Observations

The Dam Safety On Call Person responded to 95 calls in Q3, which typically includes instrumentation alarms, operational inquiries, operations notifications during high inflows and earthquake notifications. This number of calls and responses is about typical.

A magnitude 4.9 earthquake occurred 30 kilometres off the coast near Tofino at about 5:50 pm on 25 November 2022. Light to moderate shaking was reported in Tofino and weak shaking was felt in Campbell River. Our practice is to conduct post-earthquake inspections and assessments following any felt ground motions, and the Dam Safety Engineer was in immediate contact with the Stations Field Managers for North and South Vancouver Island to discuss the response. Data from instrumentation was assessed shortly after the earthquake and again the following morning with no observable changes noted. Post-earthquake inspections, carried out by trained Stations Field Operations crews, confirmed that there were no unexpected conditions at the dam sites as a result of the earthquake. Although the probability of damage to BC Hydro dams from the earthquake was extremely low, we perform these post-earthquake inspections and assessments to practice our response and identify any concerns that could impact our ability to respond to a more significant event.

7: Quarterly Dam Safety Report

Civil Maintenance

Civil maintenance on Dam Safety and Generation assets progressed well in F2023 Q3.

Table 3 Dam Safety and Generation civil maintenance for F2023.

		Quarter Q3		Year-To-Date	
		Actual	Target	Actual	Target
Corrective and Condition-Based Maintenance	Spend (\$k)	535	657	2,783	2,916
	Work Orders Completed	13	12	25/24	
Preventative Maintenance	Tasks Completed	289	270	644/749 = 86%	

Corrective and Condition-Based Maintenance

The corrective and condition-based civil maintenance program remains on track for completion in F23. The program is slightly underspent at the end of Q3, primarily due to two project start dates delayed until March due to adverse weather conditions.

The program was adjusted in Q3. Two capital projects did not require a portion of the maintenance budget allocated and several projects were completed under budget. In recognition of a projected maintenance budget shortfall throughout Stations, Dam Safety transferred the \$480k budget that was allocated to these projects to Stations Asset Planning rather than to additional Dam Safety Civil Maintenance.

One of the projects completed in Q3 was the pressure washing of the Transition Blocks at Revelstoke Dam to remove moss and emergent vegetation that was obscuring the condition of the dam's downstream exterior face. The pressure washing was completed by workers suspended in a work platform by a mobile crane on the dam deck. The project involved detailed planning, ensuring a safe rescue plan was in place, and that wash water did not enter the river. The cleaned surface was mapped and photographed to enable Dam Safety to compare past and future surveillance observations on this portion of the dam.



Figure 5 Workers pressure washing the Revelstoke Dam Transition Blocks.

Preventative Maintenance

As of the end of Q3, Stations Field Operations and Engineering Services had completed 644 preventative maintenance tasks against a plan of 749, for an 86 percent completion rate year-to-date and an improvement upon the 74 percent completion rate at the end of Q2. Again, the shortfall is largely comprised of reports in preparation.

7: Quarterly Dam Safety Report

Spillway Gate Testing and Maintenance

Spillway Gate Testing

During Q3 of F2023, all 238 scheduled gate tests at 23 sites were completed, including annual gate tests at three of those facilities. Table 4 below provides key metrics related to spillway gate testing.

Table 4 Spillway gate testing results for F2023.

		Quarter Q3		Fiscal Year F2023	
		Actual	Target	Actual	Target
Monthly Tests	Completed	238/238 =100%	100% ✓	653/653 =100%	98% ✓
	Missed	0		0	
Gates Failing to Operate on Demand during Testing	No. of failures	1		3	
	Failure rate	1/238 = 0.4%		3/653 = 0.5%	

One gate failed to operate on demand. At the Cheakamus Dam in December, the tests were performed with an outside air temperature of approximately -15°C. The two spillway operating gates operated successfully, but the low-level operating gate failed to open on command. We believe this is due to freezing of the gate, as the hoist responded to commands and the hydraulic pressures in the hoist increased until the relief valve operated. The low-level operating gate is not easily visible or accessible, so ice formation on the gate could not be confirmed at the time of the test but was observed around the facility. The low-level operating gate was tested again in early January and operated normally with an outside air temperature of approximately +3°C. No damage was noted.

Exceptions to Gate Testing Program

Gate testing scopes were reduced to exclude gate movements at some dams, as described below:

- At WAC Bennett Dam, to accommodate concrete structure upgrade work in the spillway chute.
- At Duncan Dam in October, due to rock scaling work in the spillway channel.
- At Hugh Keenleyside Dam, due to the presence of white sturgeon in the low level outlets, as discussed under “Update on Existing Issues” on page 6. The number of gate tests affected varied by month. No sturgeon were observed to be present in December, so tests on all gates were fully completed.
- In November and December, certain gate tests at Terzaghi, Mica, Elko, Duncan, and Peace Canyon dams due to freezing conditions.

Gates Out of Service or Under Restricted Service

The availability of flood passage devices is a key measure of our ability to pass high inflows and manage reservoir levels. All spillway gates and flood passage devices are currently in service. The database issues for the gates returned to service at Ruskin and Terzaghi Dams have both been closed as described on page 3. The database issue for the low level outlet gate at Hugh Keenleyside Dam, also recently returned to service, has been reviewed and is in the process of being closed.

7: Quarterly Dam Safety Report

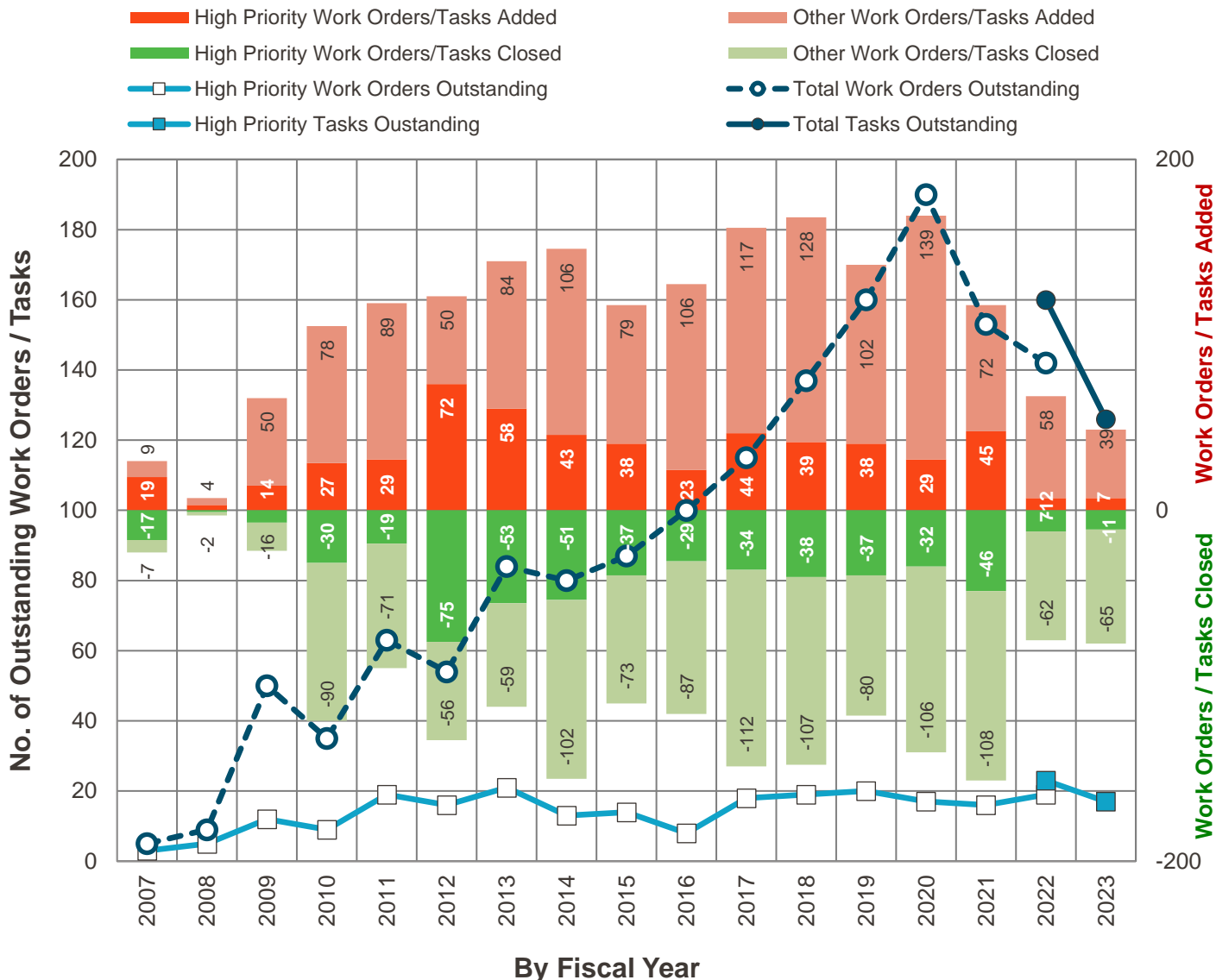


Figure 6 Number of outstanding corrective and condition-based spillway gate maintenance work orders and tasks, new work orders and tasks added, and work orders and tasks closed as at the end of each previous fiscal year.

Notes:

1. At the conclusion of F2022 moving forward into F2023, figures were restated as outstanding tasks instead of outstanding work orders to align with Operations reporting.
2. Work Orders / Tasks Added includes new work orders / tasks created in the year and identified with the gate reliability work group. It does not include work orders / tasks from previous years that were recategorized with the gate reliability work group.
3. Work Orders / Tasks Closed includes work completed through the annual maintenance program. It does not include cancelled work orders / tasks or work orders / tasks that were recategorized out of the gate reliability work group.
4. Due to notes 2 and 3, above, the net change in the number of Outstanding Work Orders / Tasks will not always equal Work Orders / Tasks Added less Work Orders / Tasks Closed

7: Quarterly Dam Safety Report

Spillway Gate Maintenance

Spillway gate maintenance results are shown in Table 5, below. Twenty-nine planned and emergent spillway gate maintenance tasks were completed in Q3, and ten new tasks were entered into the system. Work on planned tasks lagged behind the plan in Q3, partially due to access limitations in unexpectedly cold weather.

Table 5 Spillway Gate Maintenance Results for F2023.

Corrective and Condition-Based Maintenance Tasks	Quarter Q3		Year-To-Date
	Completed	Planned	
Planned Tasks	20	33	57/72 = 79%
Emergent Tasks	9		21

The number of outstanding gate maintenance tasks is shown in the chart in Figure 6 on the preceding page. Through Q3, the total number of outstanding maintenance tasks was reduced from 143 to 126. Through the first three quarters of F2023, there has been a 21 per cent decrease in outstanding maintenance tasks from 160 to 126.

“High priority” maintenance tasks are those where the asset shows moderate to severe signs of deterioration and/or its ability to perform its intended function may be compromised and failure of the asset could lead to loss of reservoir control, albeit with a long intervention time available. Through the first three quarters of F2023 – including the addition of seven new “high priority” tasks entered into the system – the number of outstanding “high priority” maintenance tasks has been decreased from 23 to 17.

Emergency Preparedness and Public Safety

Emergency Preparedness is managed by Security & Emergency Management. Dam Safety reports on the updating of emergency plans for compliance with the Dam Safety Regulation as part of annual reporting to the Comptroller of Water Rights. Public safety near dams and reservoirs is managed by the Public Safety team in Safety Engineering & Work Methods. Dam Safety reports on Public Safety activities related to dams during the Dam Safety Reviews. Please refer to the Quarterly Safety & Emergency Management Report, submitted to the Operations, Planning, and Information & Technology Committee, for updates on emergency preparedness and public safety.

Site C Clean Energy Project

Dam Safety, Generation System Operations and the Site C Clean Energy Project team are engaged in ongoing collaborations to integrate the Project’s design and construction activities and the eventually constructed facilities into BC Hydro’s Dam Safety Program.

A transition plan for Dam Safety to assume responsibilities for surveillance and management of the dam and reservoir assets as the dam enters service has been prepared.

Drafts of the revised Operation, Maintenance and Surveillance Manual for Site C Dam and Interim Dam Safety Risk Management Plan for water management at the upstream Peace River dams (WAC Bennett, Peace Canyon) that will take effect on closure and conversion of one of the diversion tunnels and will remain in effect through reservoir filling, commissioning and bringing the generating units on-line were submitted to the Comptroller of Water Rights for that office’s review. These documents will be finalized, sealed and issued in Q4.

7: Quarterly Dam Safety Report

Inundation modelling and mapping of the Alberta reaches of the Peace River for dam breach scenarios involving the Peace River dams, including the Site C Dam, is underway and scheduled for completion in Q4.

The Site C Clean Energy Project team provided Dam Safety with a progress update on development of the Geographic Information System model of the dam being developed within the Project. That model incorporates and combines three-dimensional models of the dam, generating station, foundations and other works and is being populated with geo-referenced links to the site's geological data (e.g., material properties, exploration drillholes, bedding plane and shear locations, excavation surfaces), cutoff walls and grouting records, construction and quality control records (e.g., dam body gradations and compaction test results), links to construction photos, reports and non-conformances, and installed instrumentation. It will serve as a lasting record of the dam's construction and a platform for the management of all information collected and generated through the dam's life. It is being developed along the same lines as models that have been and are being developed for other BC Hydro dams and will support the new Dam Safety Information System, described below.

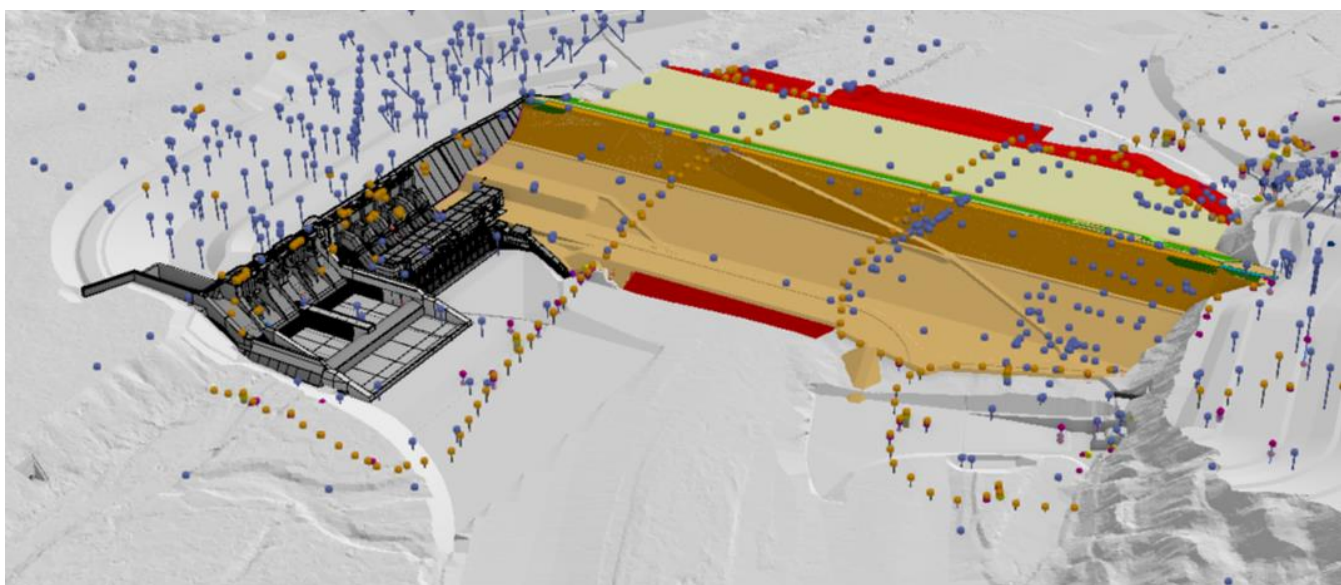


Figure 7 The Geographic Information System model of Site C Dam under development. The many “pins” on the model denote instruments that have been installed to monitor the site during the dam’s construction.

Dam Safety Information System

Release 1 of BC Hydro’s next-generation information management system was placed into service in Q3.

The Dam Safety Information System is a Geographical Information System based web application that is being developed at BC Hydro to provide Dam Safety Engineers and others efficient access to a wide array of information and data about our dams, reservoirs, adjacent and interconnected systems, and the environment in which they are all operating.

Importing data from many sources (Figure 8), the Dam Safety Information System allows users to access and visualize operating, performance and environmental information at the provincial, regional, generating river system or facility level through interactive two- and three-dimensional maps (Figure 9), drop-downs and “cards”, facilitating more complete and timely synthesis and analysis of the information for better dam safety risk management.

7: Quarterly Dam Safety Report

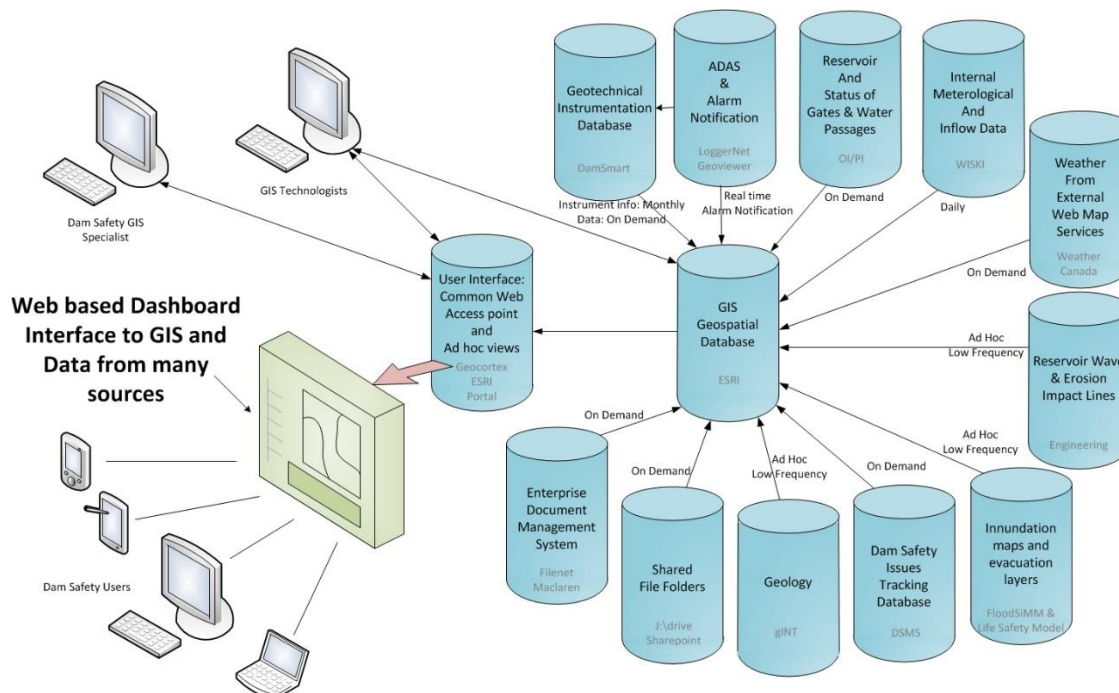


Figure 8 The Dam Safety Information System imports data and information from a wide array of internal and external sources for ready access by Dam Safety and other users.

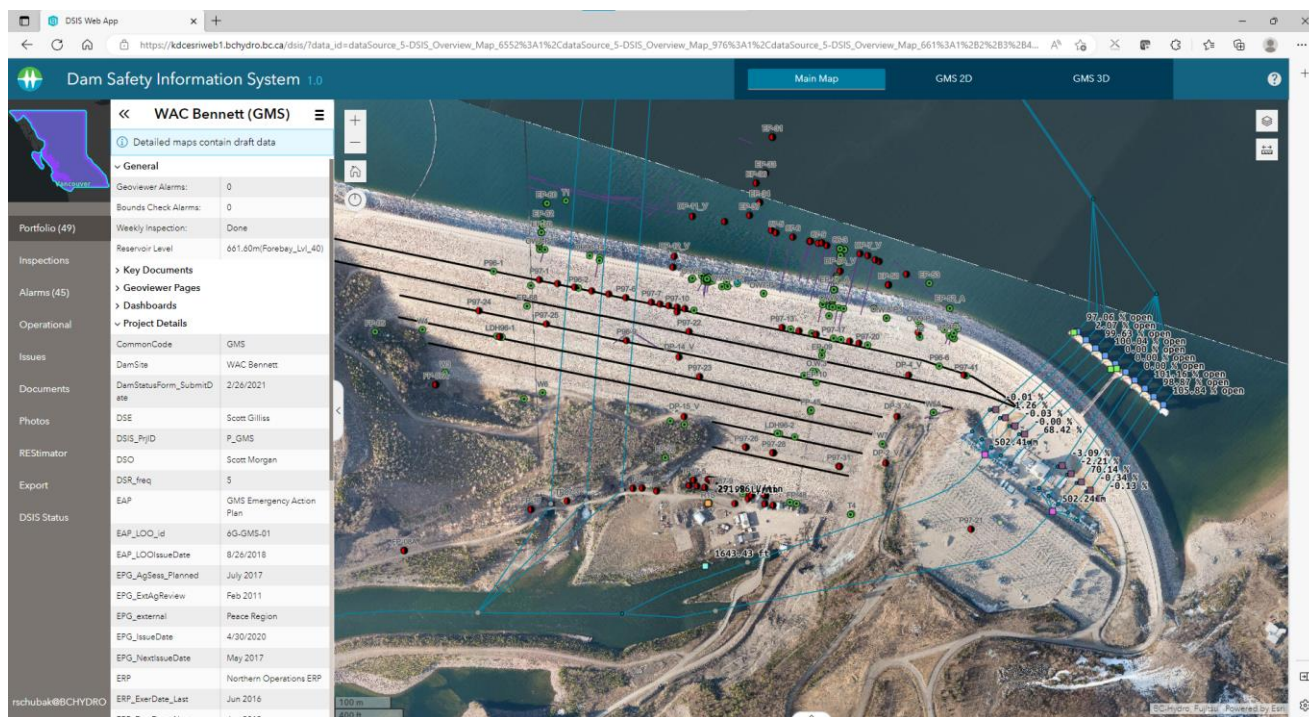


Figure 9 Main “map” of WAC Bennett Dam. Specific features of the dam such as monitoring instruments (represented by the dots) can be selected to display attributes and current readings.

7: Quarterly Dam Safety Report

The Dam Safety Information System provides, through one interface, ready access to:

- Dam Safety data and information, including real-time instrument readings and alarms from the Automated Data Acquisition System, inspection records and inspection completion status, and photographs;
- Issues tracking from the Dam Safety Issues Database;
- Key reference documents such as Operation, Maintenance and Surveillance Manuals, Operating Orders, current Interim Dam Safety Risk Management Plans, Emergency Action Plans and Planning Guides, engineering reports, and construction and investigation records;
- Generation and water passage operational data, reservoir levels and inflow forecasts; and
- Environmental information from external agencies, such as weather, avalanche conditions, historical and real-time earthquake information, and wildfires.

The concept for the Dam Safety Information System was initially proposed in 2013, and discussions on how to move to such a Geographic Information System based application followed. Piloting work on Geographic Information System models for WAC Bennett Dam and Mica Dam commenced. The project to develop this new information system was released in 2017; the Project Identification phase completed in 2018; the Project Definition phase completed in 2020. With project costs to that point of \$700,000, full Implementation at a cost of \$4.4 million was approved in 2021 and Release 1 “Go Live” was achieved on November 22, 2022.

With the core Dam Safety Information System application now in service, work is underway to expand the data sets available to users. Most notably, three-dimensional Geographical Information System models (as described for the Site C Clean Energy project, above) that can support detailed two- and three-dimensional maps within the web application are in development. Highly detailed models for WAC Bennett Dam and Mica Dam are essentially complete; similarly detailed models for Site C Dam and John Hart Dam are being produced as a part of the projects underway at those sites, and models are in development for Strathcona and Duncan Dams, with more to follow.

Release 2 of the application is currently in development and is scheduled to enter service in Q3 of F2024. Release 2 will integrate access to surveillance cameras and the earthquake acceleration estimator application, as well as enhanced access to data from the dam models described above. Integration of data sets from unmanned aerial vehicle (drone) surveillance is also being explored.

Over the coming years, the Dam Safety Information System will become the principal platform for accessing and managing information relating to the safety management of BC Hydro dams and associated assets, with continuous addition and updating of models and data and annual releases of enhancements as the application stabilizes and new requirements and opportunities are identified.

7: Quarterly Dam Safety Report

Capital Projects

Summaries of Dam Safety Capital projects are available for reference in the Dam Safety “book” in Diligent. This section of the report describes newly launched projects and provides updates for projects where significant developments occurred or milestones were achieved.

Alouette Dam – Headworks Tower and Surge Tower Seismic Upgrade

The two principal means of discharging water from the Alouette Lake Reservoir are both prone to damage – and loss of function – in the event of a major earthquake. The spillway that passes water into the Alouette River at the south end of the reservoir would undergo differential settlement that would damage its surface and render it unsafe to convey water. The tunnel that passes water to Stave Lake at the northern end of the reservoir may be blocked by rockfalls or structural failures and the tunnel gates would become inoperable by structural, mechanical and/or electrical systems failures.

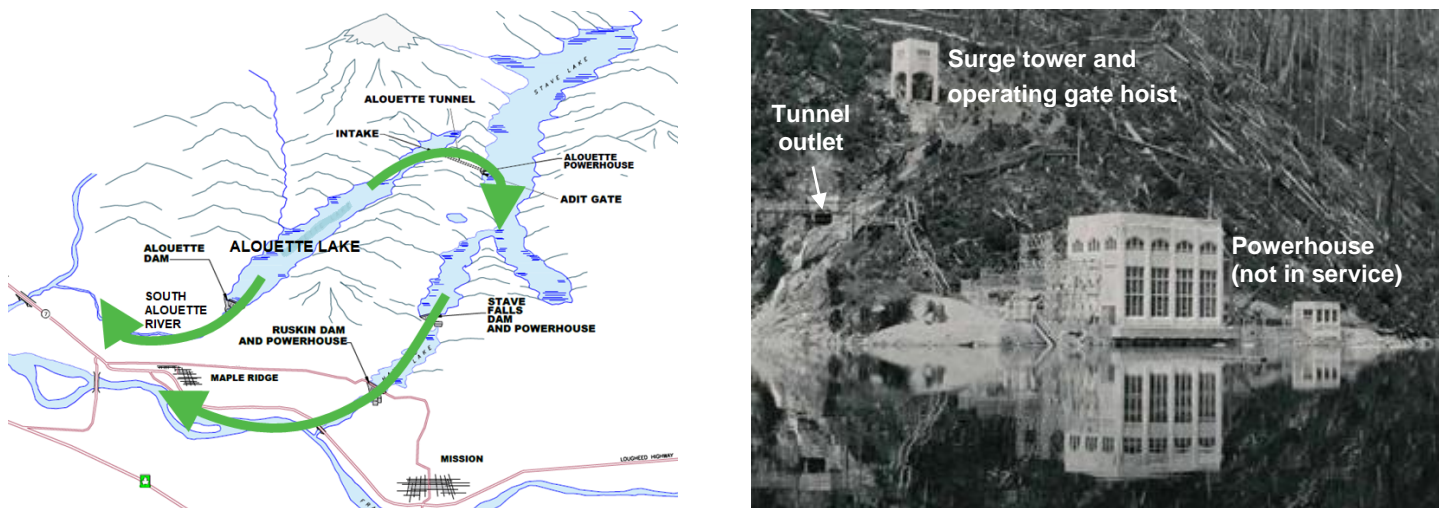


Figure 10 At left: the Alouette-Stave-Ruskin system showing the paths for reservoir discharge into the South Alouette River and into Stave Lake. At right: the Stave Lake outlet of the tunnel (photo from June 1928).

To ensure post-earthquake control of the Alouette Lake Reservoir, the preferred alternative is to upgrade the tunnel to Stave Lake. Upgrades to the tunnel are more constructible and reliable than upgrades to the spillway. Moreover, post-earthquake spilling through Stave Falls and Ruskin – both recently upgraded to withstand severe earthquakes – to the Fraser River is preferred over post-earthquake spilling into the South Alouette River and the populated areas of Maple Ridge and Pitt Meadows through which it flows. This project will implement seismic upgrades to the tunnel structures at the Alouette Lake headworks, to a concrete-lined portion of the tunnel itself, to the tunnel structures at the Stave Lake outlet (Figure 10) and to the slopes at either end. It will also replace or upgrade the mechanical, electrical, protection and control, power supply and communications equipment to support post-earthquake remote operation.

Construction will be performed in two stages: a “First Set of Works” at the Stave Lake outlet that can be performed without significant reservoir, stakeholder or First Nations impacts; and a “Second Set of Works” at the Alouette Lake headworks and within the tunnel, for which potential Alouette Lake drawdowns will require additional time to adequately consult with First Nations and engage with stakeholders. In Q3, the Gate Review Board confirmed that all aspects of the project’s First Set of Works are sufficiently advanced to proceed to construction. The project will be seeking Board approval to proceed in F2023 Q4.

7: Quarterly Dam Safety Report

Campbell River Upgrade Projects

This section provides updates regarding the **John Hart Dam Seismic Upgrade Project**, the **Ladore Dam Spillway Seismic Upgrade Project**, and the **Strathcona Dam Upgrade Discharge Project**. These projects will provide upgrades to the three major dams in the Campbell River system on Vancouver Island to address deficiencies in seismic load resistance, spillway gate reliability and flow imbalance concerns, and post-earthquake reservoir control.

A Dam Safety Advisory Board has been formed to review all three projects and provide the Director, Dam Safety with: their appraisals of the sufficiency of the work performed at key, discrete points throughout the projects' lifecycle; their determinations as to whether the projects' objectives are being met; and their recommendations for additional investigation, analysis, or design work by the projects. After an extended gap of four years, the Advisory Board was reconvened and met with the project teams in Q3. This was the fifth Advisory Board meeting for the John Hart project and the second meeting for the Ladore and Strathcona projects. The Advisory Board meetings consisted of a site visit to each of the facilities, followed by a series of presentations and meetings between the Advisory Board members, the project teams, and members of Dam Safety. Their reports were submitted to Dam Safety in January 2023.

The Advisory Board was supportive of the work done to date on all three projects and made a small number of recommendations – representing refinements rather than substantive changes – for consideration as the projects advance into detailed design and construction. The Advisory Board was particularly complimentary of the gate reliability measures that have been designed into all three projects, of which they commented “The extent and depth of the work completed to date by the Project Team for upgrading the spillway gates and their auxiliary systems are outstanding and set a standard above other hydropower companies in terms of robustness of the gate, redundancy and diversity of the power supplies, redundancy of points of control, and a seismic resistant path of the power and control cables.” The Advisory Board was further impressed by the program of seismic qualification to which the gate systems' equipment has been subjected, being unaware of any other dam owner having undertaken such prudent measures to confirm post-earthquake operability.

The John Hart project went through the gate board for End of Definition Phase in Q3 and will be seeking the Board's approval for full Implementation funding in February. The Ladore and Strathcona projects will also be seeking Board approvals in February to submit applications to the British Columbia Utilities Commission for cost recovery through rates.

Cheakamus Dam – Concrete Dam Instrumentation Upgrade

In 1985, 21 piezometers were installed in the foundation of the Main Concrete Dam to monitor uplift pressures and confirm that they remain within design values. With only eleven of those piezometers remaining functional, new piezometers were needed and remaining operational instruments required refurbishment. The project completed installation and refurbishment of the instrumentation in Q3, ahead of schedule.



Figure 11 Advisory Board with personnel from Dam Safety and the project team during the site visit to Ladore Dam.

7: Quarterly Dam Safety Report

Hugh Keenleyside Dam – Fire Protection System Upgrade

The scope of this project is to upgrade the fire protection system at Hugh Keenleyside Dam, which is not up to current standards and is in poor condition due to leaks and diminished piping wall thickness. The project will replace all accessible fire protection piping and install new piping to service currently unprotected areas including electrical galleries, combustible storage areas, warehouse and diesel generator areas. As the fire protection system is supplied with water from the Arrow Lake reservoir through a pipe – of unknown condition – embedded in the concrete dam, the project will install an isolation device on the pipe inlet to allow inspection and, if necessary, rehabilitation of the existing pipe.

In Q3 the water intake was surveyed by divers to determine its geometry and condition for designing an isolation device, and the project's Feasibility Design Report was completed.

Hugh Keenleyside Dam – Tailrace North Bank Modification

Recently, several deceased sturgeon have been found along the north (left) bank immediately downstream of the dam. Although the cause of death has not been conclusively determined, at least one fish was discovered alive and stranded on a shallow bench along the bank.

This project was released on a priority basis in Q3 to mitigate risks of stranding white sturgeon before the summer months when the fish tend to congregate in the dam's tailrace. The benched section of the north bank will be modified to mitigate the risk of future strandings. The project will construct an elevated berm along the North Bank that will act as a barrier to prevent sturgeon from being pushed onto the bench through wave action and fluctuating water levels. The berm will be overlaid with chain link fencing mesh to prevent sturgeon from being trapped in the bank's protective rip rap and to prevent smaller pieces of rip rap from potentially washing away.

Design of the berm was completed in Q3 and the application to the Dam Safety Officer to complete the work was submitted. Construction is planned to begin in May or June of 2023.

La Joie Dam – Dam Improvements

The key dam safety issues at the La Joie Dam are the ongoing deterioration of the dam's shotcrete facing and seismic deficiencies in both the dam and its intake tower, which were described in the F2022 Q2 Quarterly Dam Safety Report. As an interim risk reduction measure, Downton Reservoir has been operated at a reduced level since about 2015 until the dam is upgraded and the dam safety risks are fully addressed. The objective of this project is to upgrade the La Joie Dam, its intake tower and its other appurtenant structures to fully restore the integrity of the water barrier and to improve the seismic resistance to a level commensurate with an extreme consequence dam. The project also includes consideration of post-earthquake reservoir control and will address a number of specific issues related to the dam's discharge gates. Following the successful site investigations described in the F2023 Q1 Quarterly Dam Safety Report, the project secured endorsement to continue on to the Feasibility Design Stage in Q3.

Mica Dam – Unit 1 to 4 Intake Gate Hydraulic Power Unit and Controls Replacement

The Mica Generating Station's intake operating gates are raised and lowered by 1960s-era hydraulic systems that are becoming increasingly difficult to maintain due to scarcity of spare parts and lack of support from the original equipment manufacturer. Reliable control of the generating unit intake gates is critical for protection of equipment and personnel and for the integrity of the dam's water barrier. As the hydraulic systems continue to age, there is an increasing risk of failure. The project was released in Q3 with the single viable alternative to replace the existing systems for Units 1-4 with new systems that are consistent with the modern designs used on Units 5 and 6.

7: Quarterly Dam Safety Report

Revelstoke Dam – Marble Shear Block Rockfall Mitigation

The Marble Shear Block is a massive rock block that abuts the concrete dam and powerhouse. The Marble Shear Block underlies the spillway, and contains the compressed gas insulated bus tunnel. The most critical volume of the Marble Shear Block is heavily instrumented, and its stability is continuously monitored using a combined displacement and piezometric pressure-based threshold.

As discussed in the Q2 report and updated on page 6 of this report, on October 5, 2022, a slope failure occurred on a steep but near-surface discontinuity of the Marble Shear Block that was not instrumented, and the failed material's run-out covered the parking lot. The subsequent inspection identified cracks and rock mass features which could contribute to additional potential instabilities. There is no threat to the overall stability of the Block and its support of the dam, spillway and powerhouse, however.

The objective of this project is to ensure ongoing safe access for staff, vehicles and equipment to the Revelstoke Generating Station's parking lot and powerhouse by expeditiously providing adequate monitoring and/or stabilization measures of the Marble Shear Block. The project was released in Q3.

Terzaghi Dam – Downstream Infill Berm

A 2016 seismic performance investigation of Terzaghi dam determined that, overall, the dam would be able to withstand earthquake ground motions expected to occur, on average, once every 10,000 years, but identified two outstanding areas of concern: the downstream toe of the embankment dam is expected to suffer a small localized failure during a large earthquake which could block the tailrace of the low level outlet that is required for post-seismic drawdown; and severe earthquake shaking could cause a crack to open up between the spillway chute wall and the embankment dam, creating a possible seepage pathway. A new project was released in Q3 to address these issues by constructing a downstream berm to stabilize the dam's toe and to install a geomembrane at the chute wall interface to intercept migrating dam fills were a crack to develop.

Various – Reservoir Booms Replacement F23

This second tranche of reservoir boom replacements – at Comox, La Joie, Ruskin, Wahleach, Jordan, Elliot and Peace Canyon Dams – was released in Q3. The first tranche project was highlighted in the Q2 report with the replacement of the booms at WAC Bennett Dam and Mica Dam.

Dam Safety Investigations

Dam Safety Investigation Projects (“Investigations”) are generally performed to either refine knowledge regarding potential issues or non-conformances of information recorded in the Dam Safety Issue Database or to perform precursor work for planned capital upgrade projects. This section provides descriptions of newly launched Investigations and updates for those Investigations where significant developments have occurred or where milestones were achieved.

Dam Safety currently has 15 active Investigations underway to assess dam performance, investigate known issues, and collect additional information that is necessary to characterize the condition and performance of various dams in BC Hydro's fleet. Additionally, there are eight ongoing programs of work to update flood models, investigate seismic hazards, and improve capabilities in monitoring dams and reservoir slopes across the system.

There were no significant updates from the Dam Safety Investigations in Q3.