

## Dam Safety Quarterly 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 July 1 to September 30, 2021 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 September 30 but before the completion of this report have also been included.

This is the first report by Dam Safety to this new Committee. To provide some additional background to Committee members who have not previously received the Dam Safety report, this quarter's report has been slightly expanded to provide additional background on ongoing issues and updates on a greater number of capital improvement, investigation and maintenance projects and operational activities than is typical. We trust that, for this one report, the added material is more benefit than burden to the Committee.

The key highlights from F2022 Q2 documented in this report are:

- Following the completion of analyses and reconciliation of related issues in the database, four issues at Jordan Diversion Dam and Bridge River were closed, leading to an overall decrease of 5.55 to the aggregated Vulnerability Index. See pp. 3-5.
- The newly identified St. Cyr Landslide on the east slope of Revelstoke Lake Reservoir has been verified as existing and active. The landslide is of similar scale to Downie Slide further north on the reservoir, making it one of the largest known active landslides in B.C. See p. 6.
- Surveillance, regulatory compliance and complex civil maintenance activities are fundamentally on track to complete their planned work programs for F2022. See pp. 9-13.
- Civil preventative maintenance and spillway gate maintenance have not kept pace with their approved and funded work plans through the first two quarters of F2022. Program & Contract Management, working with Stations Field Operations and Engineering Services, have developed revised work plans that can realistically deliver the bulk of the funded work within the F2022 fiscal year. See pp. 13-16.
- Dam Safety's "Event Response Dashboard" has been put into service. This tool pulls near-real-time information together from multiple sources to provide a comprehensive view of the status of BC Hydro's dams and the availability and activities of Dam Safety personnel in responding to dam safety incidents. See p. 17.
- The La Joie Dam Improvements Project received St'at'imc Authority's letter of support for the Alternative to improve the existing dam in a way that can restore the full reservoir operating level. See p. 20.

**Presenter:** Bob Schubak, Director, Dam Safety

## Dam Safety Quarterly 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



- **Vulnerability Index (pp. 3-5):** The aggregated Vulnerability Index was reduced by 5.55 in F2022 Q2 and is forecast to remain stable or slightly reduced through the fiscal year.
- **Program Non-Conformances (p. 5):** The total number was reduced.
- **New and Current Issues (pp. 6-8):** Issues from last quarter’s report are all under active management or closed. A new landslide has been identified and plans for interim and longer term monitoring and investigation are being developed.

#### Regulatory Compliance



- **Operation, Maintenance and Surveillance Manual Updates (pp. 9-10):** The work plan has been revised to accommodate other important work and still deliver the seven planned Manual updates. The Strathcona update has since been completed and the Peace Canyon update is on track for November.
- **Dam Safety Reviews (pp. 9-10):** Work is on track with the plan.

#### Surveillance



- **Dam Inspections (pp. 10-11):** All 411 scheduled routine dam inspection were completed in Q2. Formal dam inspections and reporting are on track.
- **Reservoir Slopes (pp. 11-12):** Reservoir slopes inspections were behind plan in Q2 due to unavailability of helicopters during the wildfires. The three remaining inspections have been rescheduled to Q3.

#### Maintenance and Testing



- **Civil Maintenance (p. 12-14):** Condition-based maintenance progressed on plan. Preventative maintenance continued to lag behind the plan.
- **Spillway Gates (pp. 15-16):** The number of outstanding maintenance issues increased over Q2. All 200 scheduled gate tests were completed. One gate failed to operate due to inability to remove an upstream maintenance gate.
- F2022 maintenance work plans for civil and spillway assets have been revised to deliver most funded maintenance by year-end under increased oversight.

#### Projects and Investigations



- **Capital Projects (pp. 18-21):** The La Joie Dam Upgrade project has received endorsement from St’at’imc Authority to upgrade the dam to restore full reservoir capacity.
- **Deficiency Investigations (p. 21):** Hydraulic modelling of the Terzaghi Dam spillway and low level outlet has resolved concerns regarding spillway overtopping and has increased calculated discharge capacity.

#### Legend:



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.



One or more areas within the Program element exhibit or are at risk of underperformance and are being monitored.



One or more areas within the Program element exhibit unsatisfactory performance and require correction.



Status of the Program element has improved over the quarter.



Status of the Program element was unchanged over the quarter.



Status of the Program element deteriorated over the quarter.

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## Dam Safety Quarterly 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.

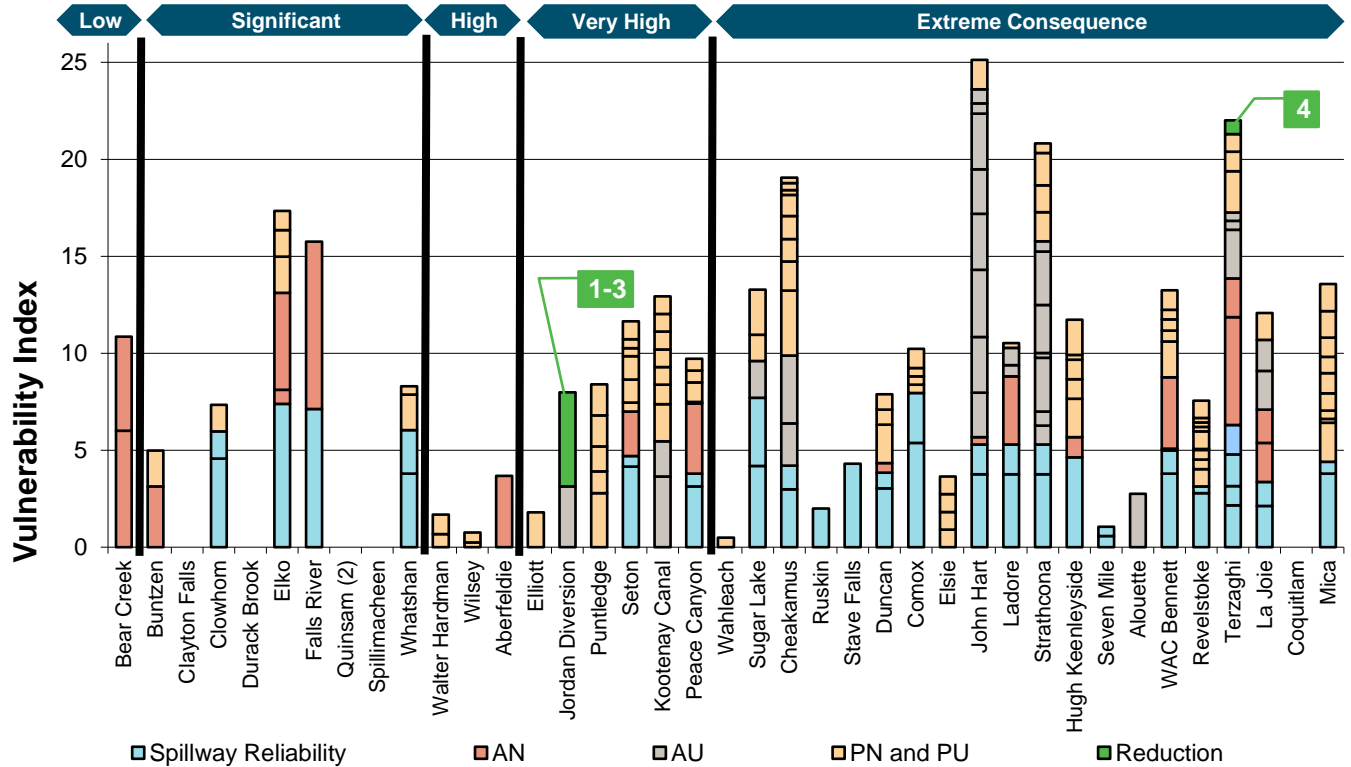
#### Vulnerability Index Update

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 F2022 Q2 are identified in Figure 1 and described below.

- 1** A **reduction** of 1.64 (Actual Unusual deficiency) at **Jordan Diversion Dam**.  
The seismic resistance of the dam’s left abutment has been considered to be inadequate, but a recently completed study has concluded that its deformation under seismic loading will not result in a loss of freeboard or uncontrolled release of the reservoir. Following the 2020 Dam Safety Review recommendation, this issue has been closed.
- 2** A **reduction** of 0.08 (Actual Unusual deficiency) at **Jordan Diversion Dam**.  
Failure of the upstream Bear Creek Dam during the Probable Maximum Flood was expected to overtop the Jordan Diversion Dam parapet wall and left abutment. However, the Bear Creek Dam has recently been reassessed as being able to withstand the Probable Maximum Flood and so this issue has been closed.
- 3** A **reduction** of 3.13 (Actual Unusual deficiency) at **Jordan Diversion Dam**.  
The Jordan Diversion Dam does not meet the performance expectations for seismic loading. BC Hydro has purchased downstream properties and installed warning signage for transient users to reduce the consequences of the dam’s potential failure in a very large earthquake. The 2020 Dam Safety Review considered these actions sufficient to close the related database issues, but we have not accepted this recommendation. We have, however, recognized that separate issues in the database for the dam’s spillway and non-overflow sections was a double-counting of the vulnerability, and so the two separate issues have been combined with a resulting Vulnerability Index reduction.
- 4** A **reduction** of 0.7 (Potential Unusual deficiency) at **Terzaghi Dam (Bridge River 2 Generating Station)**.  
Penstock rupture protection systems are installed on the generating station’s two penstocks but power cables feeding the systems apparently follow the penstocks and are thus vulnerable to penstock failure. The vulnerability of the penstock rupture protection system is captured in another database issue, however, and this redundant issue has been closed.

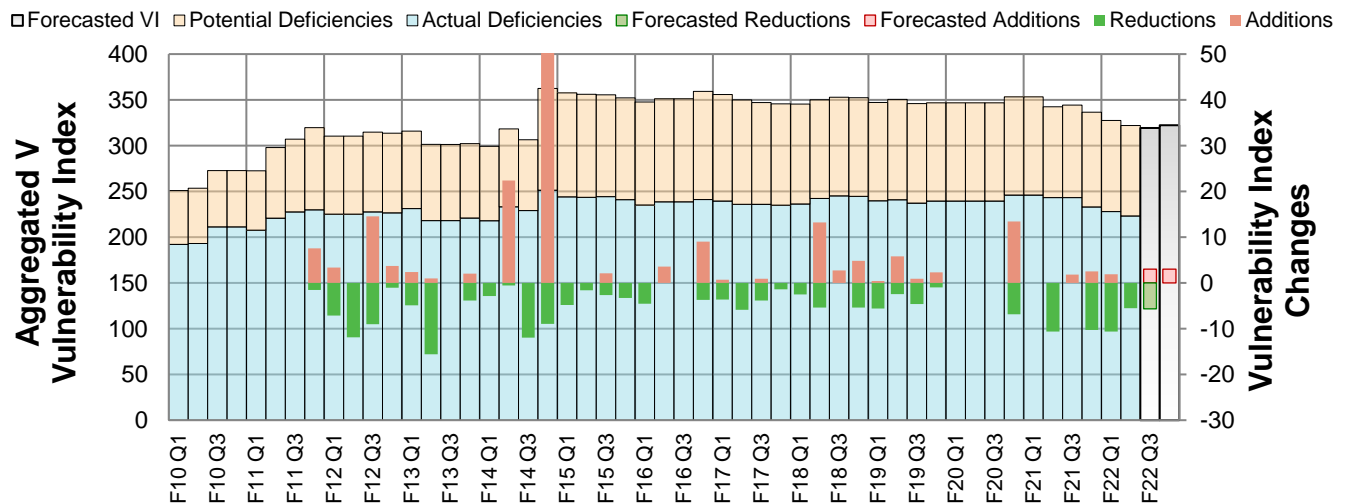
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**Figure 1** Dam Safety overall risk profile at the end of F2022 Q2, as represented by the Vulnerability Index. Changes this quarter are indicated by the numbered boxes.

- 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.

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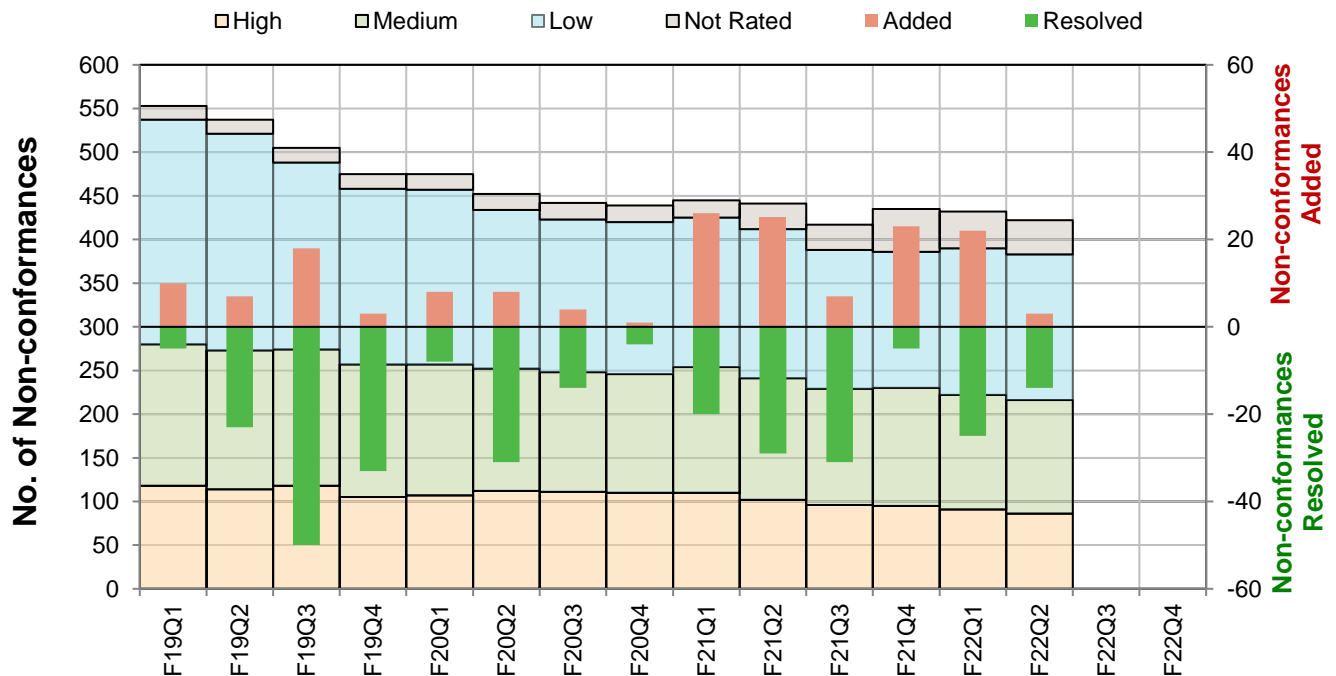
Over the last several years, new issues have added to the aggregated Vulnerability Index at a rate of approximately 12 per annum. Therefore, to prevent deterioration of the overall risk position, reductions in Vulnerability Index through resolved issues should occur at the same pace or faster. The table below confirms that this is presently the case.

		Actual / Forecast	Target
Dam Safety Vulnerability Index	Reductions - Last 4 quarters	26.5	12 ✓
	Reductions – FY forecast	21.9	12 ✓
	Additions - Last 4 quarters	6.2	

### Non-Conformances in the Dam Safety Program

Activities to identify, review, resolve and close non-conformance issues continued in F2022 Q2. Memoranda documenting reviews of the existing issues in the Dam Safety Issues Database for four sites were finalized, sealed and issued within the quarter. Resulting from those reviews was the resolution of 14 non-conformance issues. Three new non-conformance issues were added to the database for a net reduction of 11 non-conformances over the quarter.

Figure 3 shows the continuing progress in reducing the number of Program non-conformances.



**Figure 3** Changes and trends in the total number of non-conformances (characterized by level of importance) within the Dam Safety Program.



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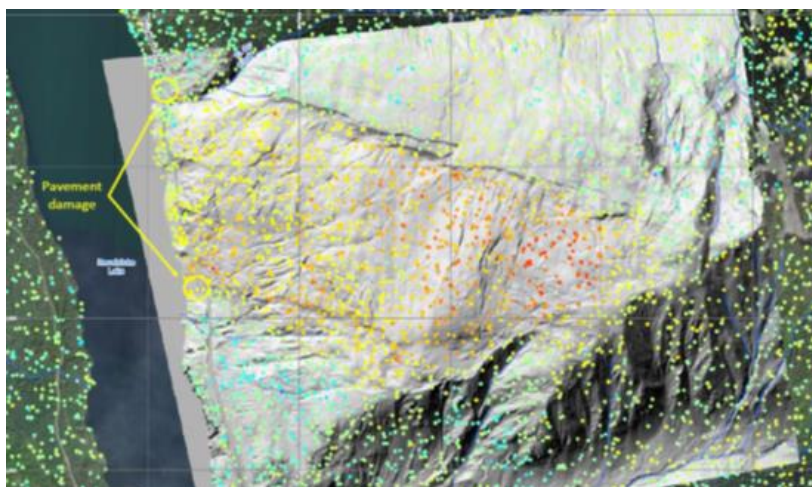
### New Issues

#### Newly Discovered “St. Cyr” Landslide

The F2021 Q4 report described Dam Safety’s partnering with the Canadian Space Agency, TRE ALTAMIRA and BGC Engineering to advance the use of satellite-acquired remote sensing (Interferometric Synthetic Aperture Radar, or “InSAR”) data for landslide detection and monitoring. Through this, a potential and previously unidentified landslide located approximately 5 km north of Revelstoke Dam, between St. Cyr and Coursier Creeks on the east side of the reservoir.

Through Q2 our Dam Safety landslide team conducted follow-up investigative work to verify the landslide’s existence. This included acquisition and analysis of airborne light detection and ranging (LiDAR) “bare earth” imaging, aerial inspection and ground inspections. Through this work our team has verified that the landslide complex dubbed as the “St. Cyr Landslide” exists and is active.

Figure 4 at right shows the “bare earth” image overlain by the satellite remote sensing displacement data (the coloured dots). The imagery shows distinct scarps along the head and sides of the slide, and the red and yellow dots that indicate larger ground velocities are very clearly aligned with the imagery. Ground inspections have further verified these remote sensing data, and pavement cracking and displacement was observed on Highway 23 along the inferred edges of the slide. Through these various means, we are of the opinion that the St. Cyr Landslide Complex exists and is active.



**Figure 4** Satellite and aerial imaging data are consistent and supported by ground observations, confirming the existence of the St. Cyr Landslide Complex.

The landslide is approximately five square kilometres in area, making it one of the larger known active landslides in the province; Downie and Branham Ridge slides are the only known active landslides larger in surface area. Preliminary estimates of the landslide volume are in the order of 900 million cubic metres. The slide may be moving a rate of up to 100 mm per year.

The discovery of this landslide is not a cause for alarm, as it has clearly been in existence for a long time. The size of the landslide and its proximity to Revelstoke Dam, however, do make it a feature of significant interest requiring further investigation and provision for ongoing monitoring. An issue has been entered into the Dam Safety Issues Database, and we are informing other potentially interested ministries, agencies, First Nations and stakeholders. Additional field investigation work scheduled this fall by the Dam Safety reservoir slopes team will investigate options for interim monitoring of the slide area, and a project is being initiated to drill and install instrumentation near the toe of the slide. To facilitate commencement of work at St. Cyr as early as 2022, consideration is being given to deferring the planned 2022 drilling project at Little Chief Landslide near Mica Dam that follows the project at Downie Slide (see “Capital Projects”). Updates will be provided to the Committee in future quarterly reports.

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### **Office of the Auditor General of BC's report "Oversight of Dam Safety in British Columbia"**

On September 14, 2021, the Office of the Auditor General of British Columbia released its report "Oversight of Dam Safety In British Columbia." That report documents an audit of the oversight of dam safety in B.C. by the Ministry of Forests, Lands, Natural Resourced Operations and Rural Development. It concludes that the ministry has not effectively overseen the safety of the province's 1,900 regulated dams.

This was not an audit of BC Hydro's Dam Safety Program and it is not an issue regarding BC Hydro dam performance, but it may prompt questions or concerns regarding the safety of BC Hydro's 83 dams. For the assurance of the Committee, Board and other readers of this report, BC Hydro is fully compliant with the requirements of the Dam Safety Regulation and all of our dams are considered to be safe, as confirmed by their most recent Dam Safety Reviews.

### **Update on Existing Issues**

#### **Dam Safety Response to COVID-19**

Dam Safety critical work continued through Q2 of F2022 without significant impact.

#### **Dam Safety Impacts from Wildfires**

The severe wildfire season did not have a large impact on the Dam Safety Program but the demand for helicopters to support firefighting efforts resulted in the need to reschedule several of the planned reservoir slopes inspections and accessing of other remote sites. Additionally, site visits for Dam Safety Reviews were deferred from Q1 to the end of Q2 and beginning of Q3.

#### **Hugh Keenleyside Dam – Navigation Lock Downstream Gate**

As reported in last quarter's report, the navigation lock at Hugh Keenleyside Dam allows marine traffic to pass through the dam. On July 15, 2021, following the passage of a tugboat and towed bundle of logs, an alarm sounded to indicate a problem on the lock's downstream gate. The gate subsequently fell from the open position to the gate sill. No one was injured in the incident.

Following the incident, engineering assessments of gate and equipment condition were performed. Dam Safety initiated a project to replace and/or repair damaged equipment and components and to return the gate to service. The project included the replacement of two damaged hoist motors, the wire rope and brake pads, and refurbishment of the hoist's sheaves. Subsequent dive inspections of the concrete sill identified no new damage as a result of the incident. The navigation lock's downstream operating gate was recommissioned and returned to service on September 1, 2021.

The final Compliance Safety Investigation report was submitted to WorksafeBC on September 15, 2021. The report details the sequence of events leading up to the incident, which are summarized as follows. At the conclusion of the annual electrical inspection of the gate's hoist system on the day before the incident, three of the hoists four brakes were improperly set in a partially engaged position, meaning that only one of the four brakes was effective. This meant that the gate, when in a raised position, had to primarily be held in place by the torque of the hoist's motors. On the next morning, after the passage of a tugboat and log bundle, the brake slip alarm was triggered. Investigations and tests conducted by the lock keeper and an attending mechanic did not identify any issues and it was decided to attempt to clear the alarms. The lock keeper did so by pushing the system's emergency stop button, which cuts off all power to the system including the hoist motors. Without power, the

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motors could not hold the gate in its raised position and the single effective brake could not stop the gate from falling to the sill.

Corrective actions are in progress and include reviewing and revising documentation and training for lock operations, maintenance, return to service procedures and pre-use inspections, and reviewing the brake design with the manufacturer. Dam Safety is developing plans for a review of asset management, operations, maintenance and public safety practices by other owners of navigable locks and canals to identify opportunities for improved management of this asset that is unique within BC Hydro.

**La Joie Dam – Failure of Intake Gate Hoisting Mechanism**

The F2021 Q4 report described the failure on March 23, 2021 of the lifting mechanism of Intake Operating Gate 4, one of two intake operating gates on the upstream end of the low level outlet referred to as the North Conduit. The North Conduit passes water through a pair of hollow cone valves directly into the Middle Bridge River during generator outages and periods of high inflows and is typically used from July through September to manage levels in Downton Reservoir. The North Conduit continues to be operated with Gate 4 open (gate dogged at deck level) and Gate 3 closed with stop logs in place upstream of the gate. The two hollow cone valves are currently open and passing water downstream.

The project to replace the failed gate “followers” for the lifting mechanisms of all four intake gates and to replace the gates and refurbish the guides for the two North Conduit gates is in progress. The replacement of the Gate 4 followers is planned to take place in the spring of 2022 when the reservoir levels are low and the North Conduit is not required to pass flows. The sequence and timing of the replacement of the other gates’ followers will be determined based on priority and outage availability. Future reports will update this work under “Capital Projects”.

**La Joie Dam – Downton Reservoir Surcharge**

The F2021 Q4 report noted the forecast for a required surcharge of Downton Reservoir this summer to prevent or mitigate spilling down the Lower Bridge River during environmentally sensitive periods and, as reported last quarter, the very hot conditions in June and July caused Downton Reservoir to rise much more quickly than forecast and above the Normal Maximum Reservoir Level of 734.0 m on July 9, 2021.

The surcharge continued throughout Q2 and was managed under an Interim Dam Safety Risk Management Plan. Downton Reservoir returned below the Maximum Normal Reservoir Level on October 22, 2021. Authorization to surcharge will be left in place through the remainder of the calendar year, however, and Generation System Operations will provide Dam Safety with regular forecasts of the reservoir’s elevation through that period.

**Mica Dam – Potential Surcharge of Kinbasket Reservoir**

As reported last quarter, the extreme heat wave in late June and prolonged hot temperatures through July resulted in record breaking inflows into Kinbasket Reservoir over that period. There was forecast to be a 30-50% probability of exceeding the Normal Maximum Reservoir Level (“surcharge”) and/or requiring spill as early as mid-August 2021 and a surcharge order permitting BC Hydro to operate up to 0.3 m above the Normal Maximum Reservoir Level from August 1 through September 30, 2021 was sought and obtained from the Comptroller of Water Rights. Ultimately, the surcharge was not required and this issue is now closed.



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### **Compliance with Processes and Regulations**

#### **Regulatory Communications – British Columbia Utilities Commission**

During F2022 Q2, Dam Safety contributed to completion and submission of the Fiscal 2023 to Fiscal 2025 Revenue Requirements Application and advancement of the documents for filing for regulatory approval of the John Hart Dam Seismic Upgrade Project. Dam Safety also contributed to a submission to the Commission’s Inquiry into the Regulation of Safety.

Work presently underway in Q3 comprises final reviews of the John Hart filing (to be submitted in Q3) and responding to Dam Safety-related Information Requests arising from the Revenue Requirements Application, the Bridge River filing and the Inquiry into the Regulation of Safety.

#### **Regulatory Communications – Comptroller of Water Rights**

Regulatory Communications with the Provincial Dam Safety Office consisted of the transmission of hard copy Dam Safety Reviews and Operation, Maintenance, and Surveillance Manuals that had previously been submitted electronically. An initial meeting to discuss the authorization process for the John Hart Seismic Upgrade Project under the Dam Safety Regulation was also held with the Provincial Dam Safety Officer.

#### **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 a requirement under the Dam Safety Regulation and must be updated every seven to ten years, depending upon the dam’s failure consequences classification.

There are seven Manual updates planned to be completed in F2022: Elsie, Hugh Keenleyside, Ladore, Peace Canyon, Puntledge, Strathcona and Sugar Lake. The work and delivery plans for the Manual updates – as at the end of Q2 – are shown in Figure 5(a). To better enable the delivery of other important work yet maintain the delivery of these seven Manuals in F2022, the work plan has been adjusted, smoothing out the progression of work and delivery of Manuals through the course of the fiscal year. The revised work plan is shown as a dashed line (the original plan is retained for reference) and the new forecast for Manual completions is overlaid on the original completion schedule. At the time of writing, the Manual for Strathcona Dam had been completed and issued on plan in October and the Manual for Peace Canyon Dam was on schedule for completion in November.

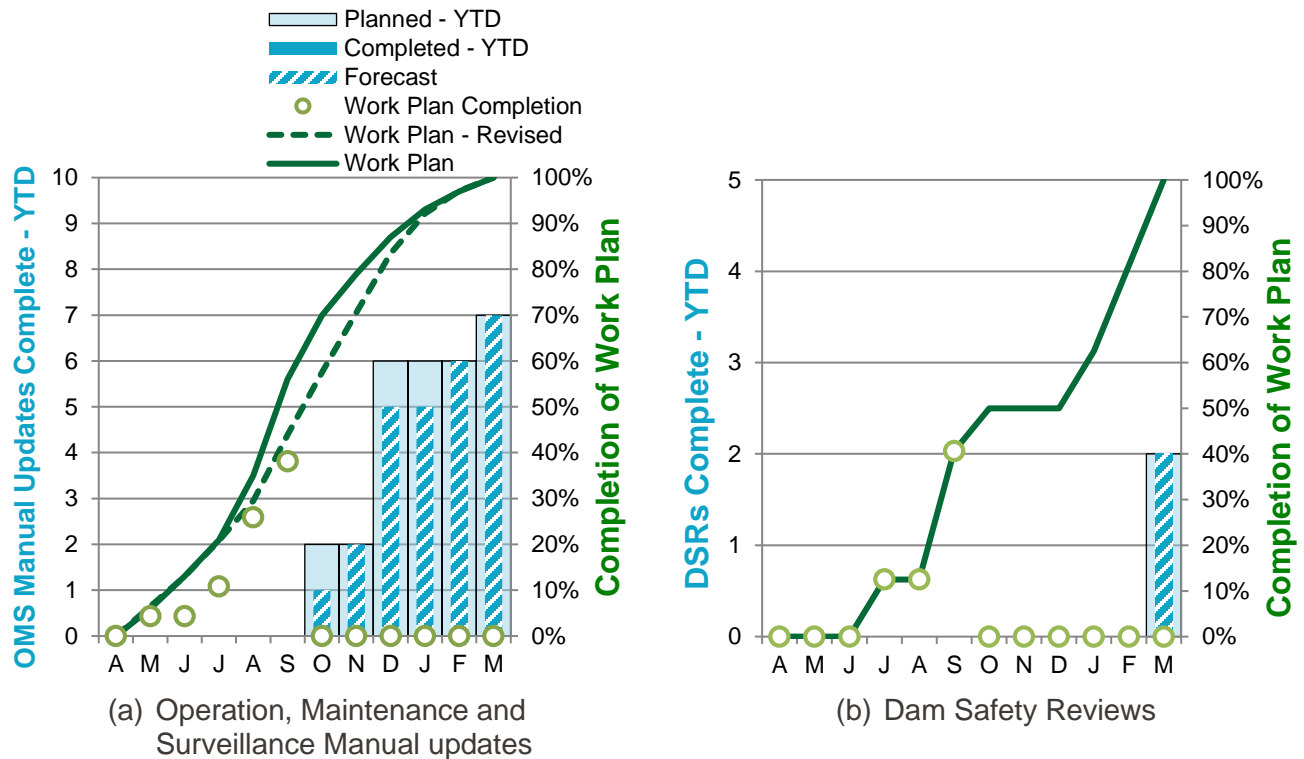
#### **Dam Safety Reviews**

Dam Safety Reviews 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.

The work and delivery plans for the Dam Safety Reviews are shown in Figure 5(b). Only two Dam Safety Reviews are scheduled to be fully completed and issued in F2022: La Joie and Seton. Site visits by the Dam Safety Review engineers were completed in September 2021. These Dam Safety Reviews are scheduled to be completed and issued in March of 2022. Work on two other Dam Safety Reviews – for Terzaghi and Wahleach – will proceed just slightly behind but aren’t planned to be completed until early in F2023.

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**Figure 5** F2022 work and delivery plans for (a) Operation, Maintenance and Surveillance Manual updates and (b) Dam Safety Reviews.

**Surveillance**

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

		Quarter Q2		Year-To-Date	
		Actual	Plan	Actual	Target
Routine dam inspections	Completed	411/411 = 100%	100%	819/822 = 99.6%	99.5% ✓
	Missed	0		3	
Formal (annual and semi-annual) dam inspections	Field work completed	10	35	53	55 ✗
	Reports issued	13	10	28	10 ✓
Instrumentation data checks		198/195 = 102%	95%	385/390 = 98.7%	95% ✓
Reservoir Slopes inspections	Field work completed	5	8	7	10 ✗
	Reports issued	0	0	0	0

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### **Dam Inspections**

#### *Routine 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. As shown in the table on the next page, all the 411 scheduled site inspections were completed in Q2.

#### *Formal 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.

In F2022 Q2, the field work for these inspections was completed at 10 dam sites resulting in a year to date total of 53 sites completed, just slightly behind the original internal work plan of having completed the field work at 55 sites. This is the result of having shifted the priority for some of the Dam Safety Engineers to completing and issuing the inspection reports for sites already inspected prior to commencing work at different sites. Consequently, the completion of 28 final inspection reports through the end of Q2 was well ahead of the internal work plan target of 10. Completion of the field work for all 71 formal inspections for the year is well in hand and, overall, the program of formal inspections is on track.

### **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. During Q2, 198 checks were completed on a plan 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.

In Q2, the demand for helicopters to support firefighting efforts resulted in the need to reschedule several of the planned reservoir slopes inspections. As a result, inspections planned for July and August were rescheduled to September and October. Field work was completed for five sites in Q2. Of the remaining three sites, one inspection was completed in October and weather conditions have forced rescheduling the final two inspections to November. Additional work performed in Q2 to

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confirm the newly identified St. Cyr Landslide (see “New Issues”) consisted of an aerial Light Detection and Ranging (known as “LiDAR”) scan and ground inspections.

**Unusual Events or Observations**

The Dam Safety On Call Person responded to 66 calls in Q2 of F2022, which included instrumentation alarms, operational inquiries, operations notifications during high inflows and earthquake notifications. This number of calls and responses is consistent with expectations and past experience. None were sufficiently noteworthy for inclusion in this report.

**Maintenance and Testing**

**Civil Maintenance**

		Quarter Q2		Year-To-Date	
		Actual	Target	Actual	Target
Corrective and Condition-Based Maintenance	Work Orders Completed	12	11 ✓	13/12 = 108%	90% ✓
	Spend (\$k)	1,495	1,955	2,716	2,894
Preventative Maintenance	Tasks Completed	297/355 = 84%	90% ✗	406/545 = 74%	90% ✗

*Corrective and Condition-Based Maintenance*

The Civil Maintenance program for corrective and condition-based maintenance continued to progress well through Q2. As forecast in the Q1 report, a Change Notice was finalized in Q2 to accommodate maintenance budget pressures arising from unplanned costs to respond to the La Joie intake gate hoist failure (see “Update on Existing Issues”). This revision reduced the number of planned Civil Maintenance projects in F2022 to 26 from 38 and reduced the budget to \$3.6 million from \$4.0 million. Twelve projects were completed in Q2 against the revised plan of eleven and year-to-date spend was \$2.72 million against a revised plan of \$2.89 million.

Repairs of the Boulder Creek Dyke at Wahleach were completed in Q2 to address undermining near the dyke’s toe. The repair included excavating a toe trench and placing riprap in the toe trench, up the remainder of the bank and grouting it in place. The project was significant in size, requiring construction of a temporary dam and diverting the creek through a conduit. See Figure 6. The project accounted for over \$0.5 million of the program’s forecast annual expenditures of \$3.6 million.



**Figure 6** Water diversion in place at Boulder Creek and rip rap placement occurring at the dyke toe.



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Peace Canyon spillway bay 3 and 4 concrete repairs were also completed in Q2. This included the repair of a crack in bay 3 (Figure 7) and two spall repairs in bay 4 near the Spillway Operating Gate sills. This location is difficult to access and required several measures to ensure the safety of the construction personnel while performing the work as well as our ability to recall the spillway if needed, including: an Interim Dam Safety Risk Management Plan, engineered mechanical blocking and basket lifts of personnel to and from the work location from the spillway bridge, and confined space and fall protection procedures. Work was performed by Construction Services with engineering design and support by the Stations Maintenance Civil Engineering team. Project expenditures were approximately \$135,000.



**Figure 7** Peace Canyon Dam spillway concrete repairs: (Left) Location of repairs; (Upper right) crack in bay 3 between stoplog and spillway gate sills; (Lower right) repaired crack.

The other projects completed in Q2 were: Mica right abutment access improvements, flip bucket road rockfall protection, and spillway debris boom repairs; Illecillewaet pump house trashrack clearing and discharge pipe inspection; Aberfeldie penstock excavation and repair; Cheakamus tunnel shotcrete repair; Stave Falls spillway gate sill concrete repair; Falls River spillway stanchion removal; WAC Bennett spillway debris boom repairs; and Puntledge intake flashboards inspection.

### *Preventative Maintenance*

In Q2 Operations and Engineering Services completed 297 civil preventative maintenance work orders against a plan of 355. Through the course of the first two quarters, 406 of 545 work orders had been completed, significantly lagging behind the plan established prior to the fiscal year start, as shown in the table on page 12.



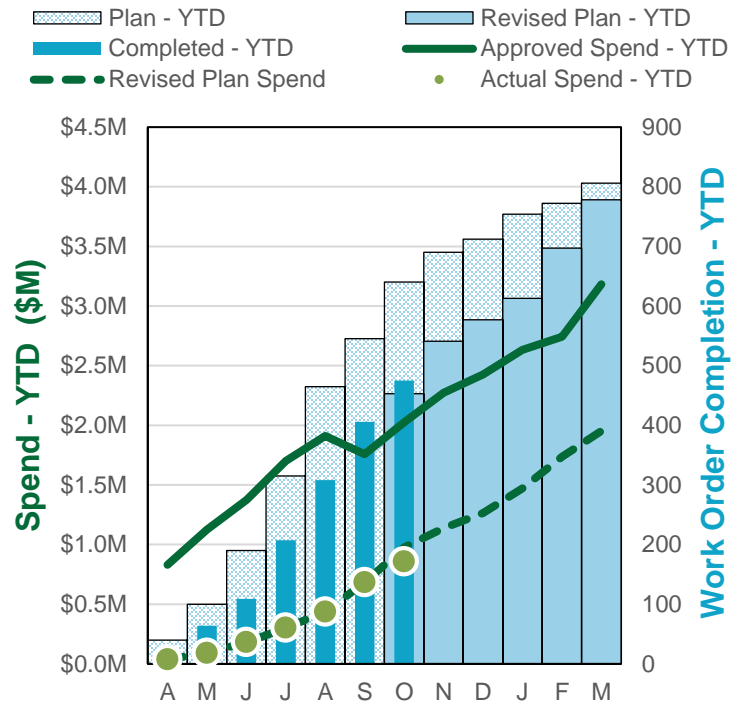
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Dam Safety has expressed its concerns regarding this completion rate and in response, through October, Program and Contract Management worked with Stations Field Operations and Engineering Services to:

1. ensure that work order scheduling and completion was properly recorded;
2. ensure that funded and approved but uncompleted work orders had been appropriately scheduled for action and completion through the remainder of the fiscal year; and
3. develop a revised schedule for completion of 778 of the funded inventory of 806 civil preventative maintenance work orders through the course of F2022.

The originally approved plan, revised plan, and actual completions and spend for civil preventative maintenance are plotted in Figure 8, at right.



**Figure 8** Revised F2022 work plan for completion of civil preventative maintenance work orders.

In delivering on this revised plan, of which Program & Contract Management, Stations Field Operations and Engineering Services have expressed confidence, the F2022 targets and objectives for preventative maintenance of dam, reservoir, water passage and generation-related civil assets will have been essentially met. Program & Contracts Management is improving tracking and reporting to better support Dam Safety in monitoring progression of the work plan on a monthly basis. A series of monthly meetings has been established between the Directors of Dam Safety, Stations Field Operations and Program & Contracts Management to review the results and provide timely direction to address divergences from the plan.

Through deferrals and extensions of some work orders and prorating actual-to-estimate costs achieved in the first seven months through the remainder of the year, the forecast spend on civil preventative maintenance has been reduced from \$3.2 million to just under \$2.0 million.

### Spillway Gate Testing and Maintenance

#### *Spillway Gate Testing*

The table on the following page provides key metrics related to spillway gate testing. During Q2 of F2022, all 200 scheduled gate test operations at 23 sites were completed.

One gate could not be operated on demand during Q2. At Stave Falls Dam, the gantry crane was used to deploy the maintenance gate to facilitate concrete repairs on the spillway. Near the end of the maintenance work, the gantry crane failed to operate, leaving an operating gate isolated behind the stuck maintenance gate and unavailable to operate on demand during monthly spillway gate testing.

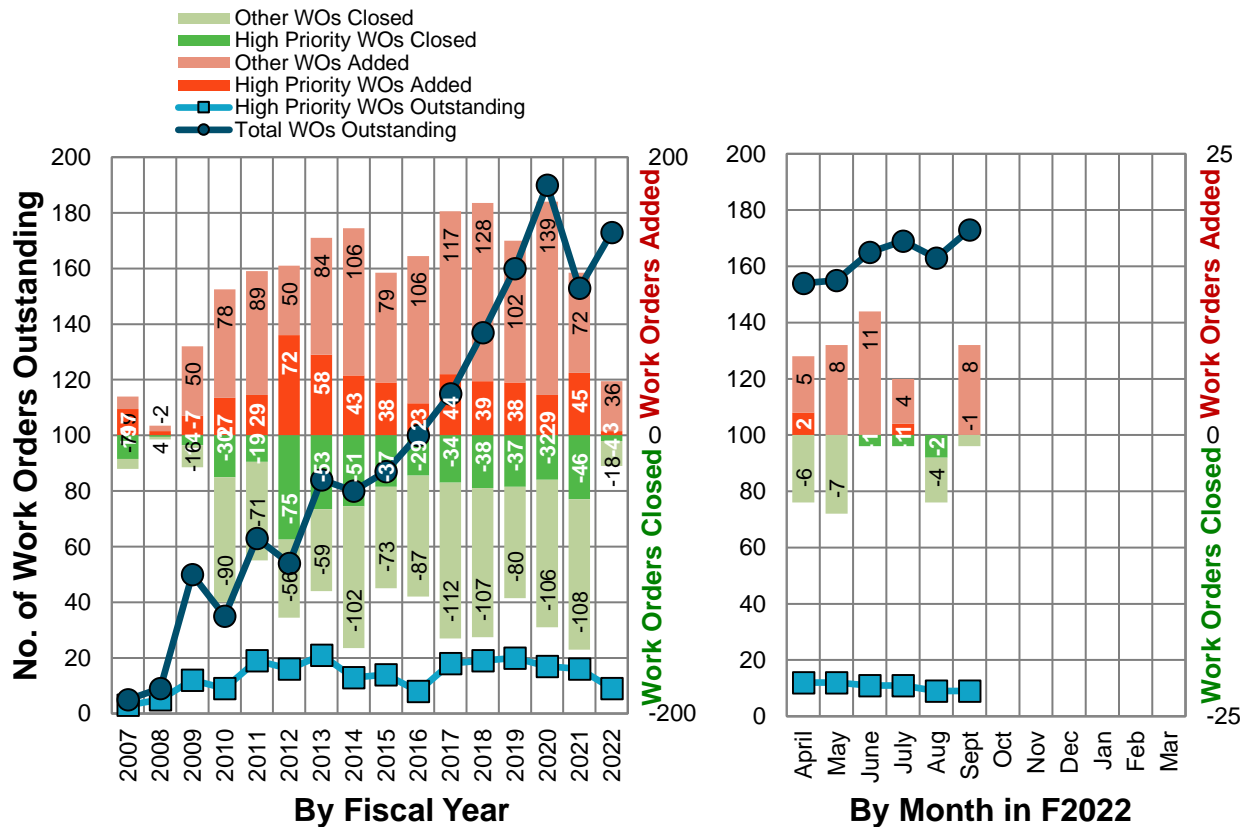
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		Quarter Q2		Year-To-Date	
		Actual	Target	Actual	Target
Monthly Tests	Completed	200/200 = 100%	100% ✓	419/421 = 99.5%	98% ✓
	Missed	<b>0</b>		<b>2</b>	
Gates Failing to Operate on Demand during Testing	No. of failures	<b>1</b>		<b>4</b>	
	Failure rate	1/200 = 0.5%		4/394 = 1.0%	

*Spillway Gate Maintenance*

The number of outstanding gate maintenance work orders is shown in the chart in Figure 9. The total number of outstanding work orders increased from 165 to 173 in F2022 Q2, while the number of “high priority” maintenance work orders has decreased from 11 to 9. “High priority” gate maintenance work orders 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.



**Figure 9** Number of outstanding corrective and condition-based spillway gate maintenance work orders, new work orders added, and work orders closed as at the end of each previous fiscal year and the end of each month in the current fiscal year.

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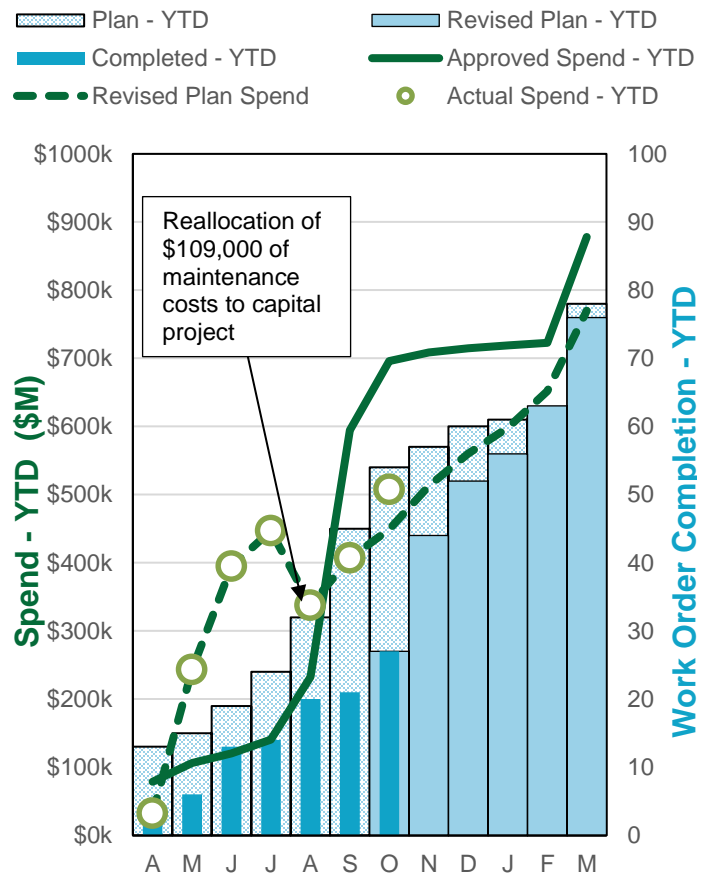
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Again, Dam Safety has expressed its concerns regarding this completion rate and Program and Contract Management worked with Stations Field Operations to develop a revised schedule for completion of 76 of the funded inventory of 78 spillway gate maintenance work orders through the remainder of F2022. It is expected, however, that six additional work orders are likely to be deferred until F2023 due to physical factors preventing their completion.

The originally approved plan, revised plan, and actual completions and spend for spillway gate maintenance are plotted in Figure 10, at right.

In delivering on this revised plan, of which Program & Contract Management and Stations Field Operations have expressed confidence, it is anticipated that the number of gate maintenance issues resolved will approximately just offset the number of new issues identified through F2022.

As for civil preventative maintenance, the Directors of Dam Safety, Stations Field Operations and Program & Contract Management will meet monthly to review the results and provide timely direction to address divergences from the plan.



**Figure 10** Revised F2022 work plan for completion of spillway gate maintenance work orders.

**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 Safety & Emergency Management Quarterly Report for updates on emergency preparedness and public safety.

**ShakeOut 2021 – Event Response Dashboard**

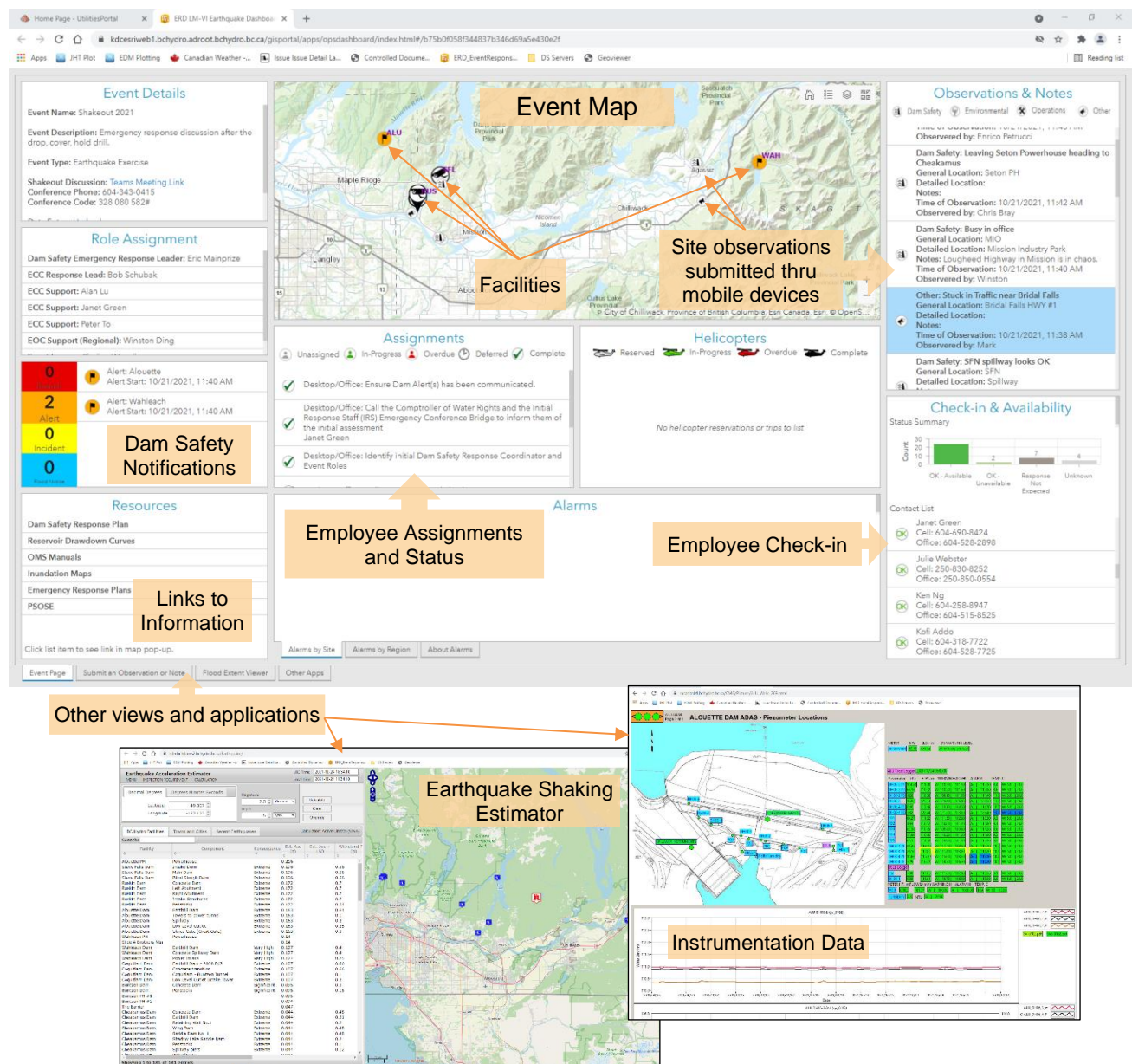
The F2021 Q2 Dam Safety Quarterly Report highlighted the development of the Event Response Dashboard, which pulls together near-real-time information from provincial and BC Hydro emergency management systems and Dam Safety instrumentation systems, links to emergency response plans and inundation maps, and tracks employee check-ins, status of assigned tasks, observations (including photographs), and Dam Alert and Dam Breach notifications. Tracking entries are made in simple Excel spreadsheets that can be maintained offline if network access is disrupted.

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Since last reported, the dashboard has been put into service and upgraded to include the ability to use mobile devices to view the dashboard and input observations and photographs from the field.

Dam Safety conducted a small table-top exercise following the Great British Columbia ShakeOut on October 21, using the dashboard to simulate response to a scenario Magnitude 7.5 earthquake in the Lower Mainland. A screen shot of the dashboard during the exercise (with some added annotations to identify various dashboard features) is shown in Figure 11, below. The dashboard is ready for use in an emergency dam safety event. While it's been designed for use in emergencies, Dam Safety personnel are being encouraged to regularly use the dashboard during routine field work (inspections, instrumentation maintenance and installations) to gain familiarity and comfort with this new tool.



**Figure 11** Annotated screen shot of the Event Response Dashboard taken during the exercise held in connection with the Great BC ShakeOut on October 21, 2021.



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### Capital Projects

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

#### Various Sites – Reservoir Booms Replacement

The scope of the project includes the replacement of aging and deteriorating debris booms at Mica, Terzaghi, Sugar Lake, Cheakamus, Stave Falls, Clowhom and WAC Bennett Dams with new, next-generation reservoir booms that meet both debris interception and public safety requirements.

As of the end of Q2, the boom alignment and configuration designs at all seven facilities were substantially complete, preliminary design of the Mica and WAC Bennett booms was well underway, and a Request for Proposal on a master service agreement to supply boom components for the replacement of all seven facilities’ booms had been issued.



**Figure 12** The “next generation” reservoir boom at Seven Mile Dam.

#### Bridge River 2 – Strip and Recoat Penstock 2 Interior

Bridge River 2 Penstock 2 supplies Units 7 and 8 and is one of two penstocks for Bridge River 2. The exteriors of the Bridge River 2 penstocks were recoated in 2008 to 2011 and the interior of Penstock 1 was recoated in 2019. This project is to recoat the interior of Penstock 2, the adjacent tunnel liner and Units 7 & 8 scroll cases. In Q2 the project completed the installation of new permanent access hatch covers and recoating of the scroll cases. Penstock interior re-coating is planned to take place in March to June 2022.

#### Cheakamus – Recoat Units 1 and 2 Penstocks (Interior and Exterior)

The scope of this Project is to strip the old, failed coatings on the exterior and interior surfaces of Cheakamus Penstocks 1 and 2 and the exposed surface of the steel lined tunnel and recoat them to prevent further corrosion and extend the life of the assets. Supporting scope includes the installation of hatches and fall arrest systems on the penstocks, construction of a new access road, and vegetation removal around the penstock for access. The Penstock 1 interior coating and hatch installations were completed in Q2. Construction work for Unit 2 penstock interior recoating will coincide with the planned Unit 2 outage in early 2022.

#### Coquitlam / Lower Buntzen 1 – Tunnel Gates Refurbishment

The Coquitlam-Buntzen Tunnel Inlet was built in 1903 and modified in 1911. The facility is constructed in natural rock with all gates installed in fixed locations 27m underground. The tunnel’s single maintenance gate was partially refurbished in 1955. The two operating gates downstream of



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the maintenance gate are original from 1911 and have a history of mechanical problems resulting in reliability issues, particularly at high reservoir elevations. The project objective is to ensure the reliable operation of the intake operating gates to meet legal and regulatory requirements to manage Coquitlam reservoir elevations and to support generation at Lake Buntzen 1 Generating Station.

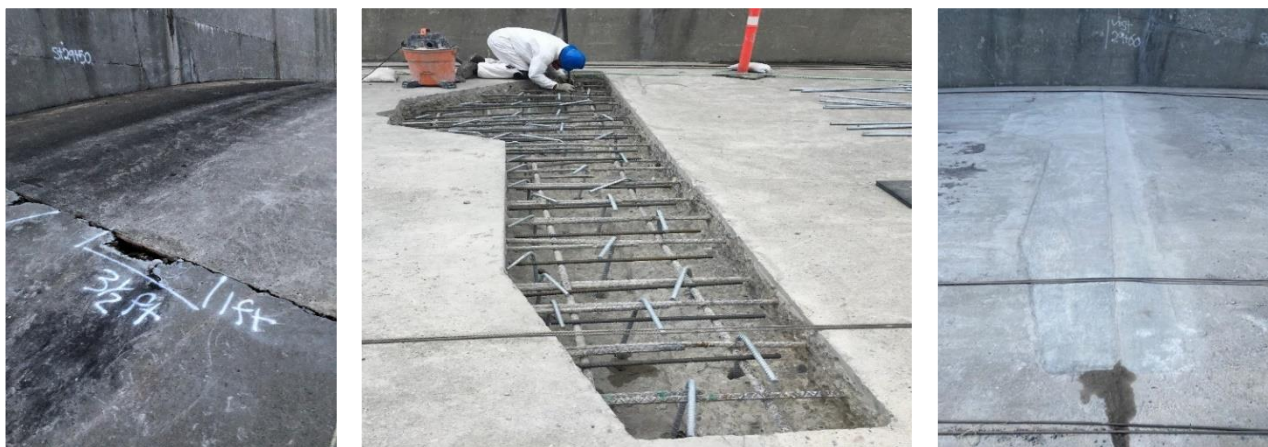
The project completed its second construction outage in Q2, which included drilling a new intake maintenance gate shaft and installing a new gate frame. Due to gearbox damage sustained during factory testing, the new maintenance gate could not be fully installed and commissioned as planned. A revised construction plan is being developed, which may necessitate the need for an additional construction outage. The project's scheduled in-service date is April 2022, but this may be delayed to November 2022.

### GM Shrum (WAC Bennett Dam) – Spillway Concrete Upgrades

The objective of this project is to upgrade the spillway chute's concrete surface to ensure continued safe operation of the spillway. This project follows the Spillway Chute Upgrade Project, completed in 2016, which identified damage throughout the entire length of the spillway chute and remediated the highest priority areas located immediately upstream of the flip bucket. The specific sections of the spillway chute to be remediated as part of this project are the next highest priority sections in the inclined chute, both above and below the previously resurfaced area.

The contractor was unable to complete the planned scope of work during this year's available construction window, attributable to a month-long delay in the start of construction due to operational spill requirements and a significantly lower rate of concrete demolition than had been anticipated by the contractor. The project team has, however, assessed the work that has been completed to be of high quality. Figure 13 shows "before", "during" and "after" conditions of one remediated joint in the spillway.

The project team is reviewing the results of a trials using small hydro-demolition units, after which it will develop options to address the remaining scope of work and will present them to Dam Safety for consideration in Q3.



**Figure 13** Before (left), during (middle) and after (right) views of one remediated construction joint (Station 29+60) in the spillway at WAC Bennett Dam.

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### GM Shrum (WAC Bennett Dam) – Intake Operating Gates Hydraulic Upgrade & Gate Refurbishment

This project was released in Q2 and encompasses the hydraulic upgrade of the intake operating gates and the refurbishment of the intake operating gates and intake maintenance gates. The objective of this project is to extend the life of the intake operating and maintenance gates as well as upgrading the hydraulic system to address identified deficiencies and reliability issues.

### La Joie – Dam Improvements

The key dam safety issue at La Joie Dam centres around the ongoing deterioration of the dam's shotcrete facing. The shotcrete is prone to cracking and buckling over time as the dam undergoes dimensional changes in response to ongoing settlement and temperature changes, requiring extensive annual maintenance to control through-dam seepage. Please see "Corrective and Condition-based Maintenance" in last quarter's report for a report on the completion of this year's maintenance. Refer also to Figure 15, below right.

Following a large earthquake, it is expected that the dam will deform significantly, further damaging the shotcrete face and allowing high rates of prolonged leakage through the dam that could potentially destabilize the rockfill structure. The dam's intake tower is also considered to be seismically deficient. Risks are currently being managed by annual shotcrete repairs and by having lowered the maximum reservoir level by 16 metres, limiting the total amount of water stored in Downton Reservoir so that the water released in the event of a post-earthquake failure of La Joie Dam would not overtop Terzaghi Dam downstream.

The objective of this project is to upgrade 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.

In Q2 the project achieved a significant milestone; it received St'at'imc Authority's letter of support for the Alternative to improve the existing La Joie Dam, as described above, in a manner that can restore the full reservoir operating level. Conditions of the endorsement include the continued engagement with St'at'imc on all major project decisions, agreement on a process for flow management, procurement opportunities, and funding for continued engagement/ working group activities. The Project will be seeking endorsement for this improvement as the Leading Alternative and for funding to complete the Conceptual Design Stage in November 2021.



**Figure 14** La Joie Dam and intake tower at low reservoir.



**Figure 15** Large repair area chipped open and exposed on the face of La Joie Dam during this year's annual maintenance.

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### Revelstoke – Replace Downie Slide Instrumentation

The objective of this project is to replace existing conventional slide-monitoring instrumentation at the Downie Slide that is failing due to ongoing slide displacement, and to implement a new deformation monitoring system that uses continuous Global Positioning System (GPS) technology that is not prone to such failure. The project completed installation of three new piezometers and eleven inclinometers – drilled and installed to depths ranging from about 200 metres to 275 metres – and twelve continuous Global Positioning System towers in Q2. Contractors demobilized from the site in October. The connection of the new instrumentation to Dam Safety’s Automated Data Acquisition System is expected to be complete by the end of Q3.

This successful project is the exemplar for a subsequent project to replace the instrumentation on Little Chief Slide at Mica Dam and, potentially, for instrumentation of the St. Cyr landslide described under “New Issues”.



**Figure 16** A new continuous Global Positioning System tower on Downie Slide.

### **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.

#### Terzaghi – Hydraulic Assessment of Spillway

The objective of this Investigation is to assess potential deficiencies of the Terzaghi spillway capacity and its ability to pass floods. The Engineering team developed a three-dimensional computational fluid dynamics model to assess the hydraulic performance of the Terzaghi spillway for a range of operating scenarios. The draft report has been completed and submitted to Dam Safety for review.

The new spillway and low-level outlet discharge rating curves produced from the computational fluid dynamics modelling indicate that 88% of the estimated Probable Maximum Flood could be passed with the reservoir at the top of the dam’s “core wall”, and 97% of the estimated Probable Maximum Flood could be passed with the reservoir at the top of the dam’s “splash wall”, representing a significant improvement in the calculated flood routing capability of Terzaghi Dam. Engineering has recommended a full Probable Maximum Flood study be undertaken to resolve remaining uncertainties in the Probable Maximum Flood magnitude and reservoir routing assumptions. The Investigation also concluded that the risk of overtopping the spillway chute’s left wall is low for either partial or fully open spillway operating gate operation up to the normal maximum reservoir level. With the spillway operating gates fully open at higher reservoir elevations, some overtopping of the chute wall adjacent to the earthfill dam may occur, but under these circumstances the risk of erosion of the downstream dam slope appears to be very low. Once the report is finalized, the database issues and their associated Vulnerability Indices will be revised to reflect these new findings.