Discussion/Information

Board briefing – DAM SAFETY QUARTERLY REPORT

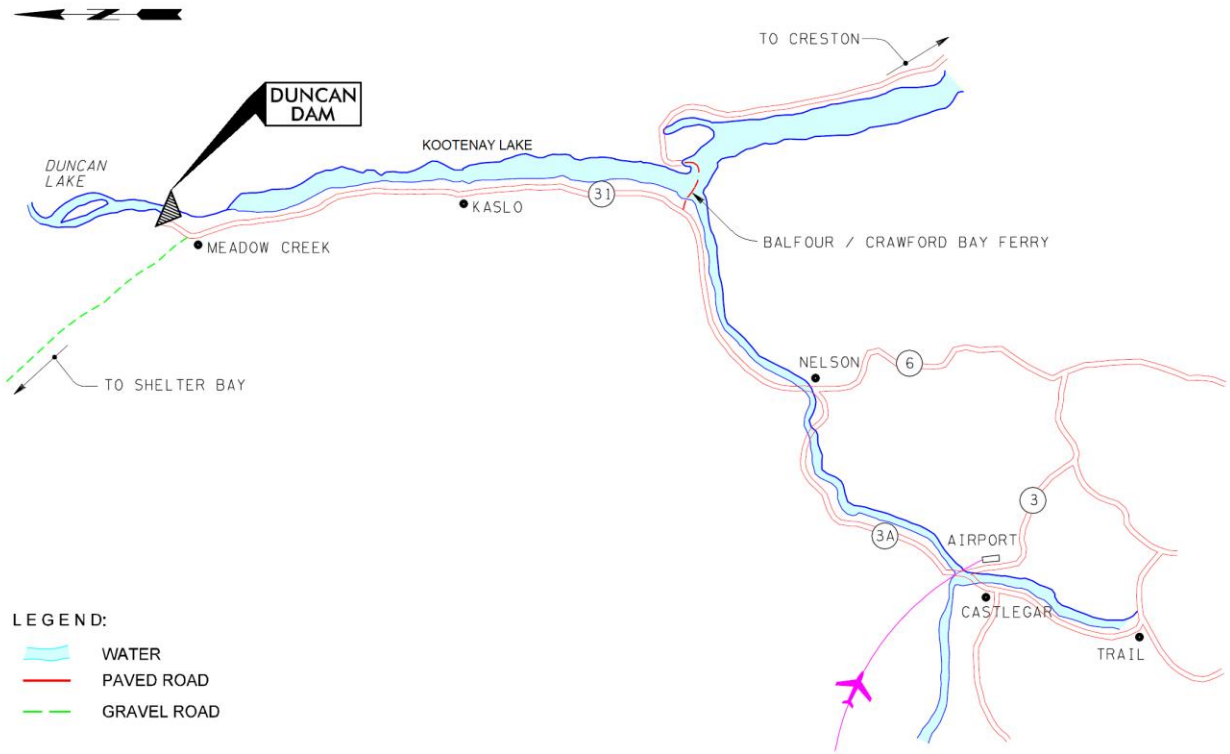
Executive Summary

The purpose of this report is to update the Capital Projects Committee of the Board of Directors on key dam risk management activities during the period from July 1, 2018 to September 30, 2018, 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.

The Dam Safety Program has been carried out consistent with its stated objectives throughout the reporting period. The overall Dam Safety risk profile is shown in Figure 1. There has been an overall increase in risk this quarter with the observation of fine material deposited downstream of Hugh Keenleyside Dam, updated stability assessments of the Cheakamus dams under flood loading and the penstock under seismic loading and ongoing deterioration of the concrete in Wilsey Dam. There have been decreases in risk due to completion of concrete repairs on the Seton Canal and an assessment of the Mica Intake Tower under seismic loading.

Quarterly Featured Damsite – Duncan Dam Updated

The Duncan Dam is an Extreme consequence dam located immediately upstream of the confluence of the Duncan River and Lardeau River, about 8 km upstream of the north end of Kootenay Lake and 42 km north of Kaslo, B.C. Duncan Lake is surrounded by moderately to steeply sloping mountainous terrain. Discharges from the facility provide inflow regulation to Kootenay Lake.



Duncan Dam Location

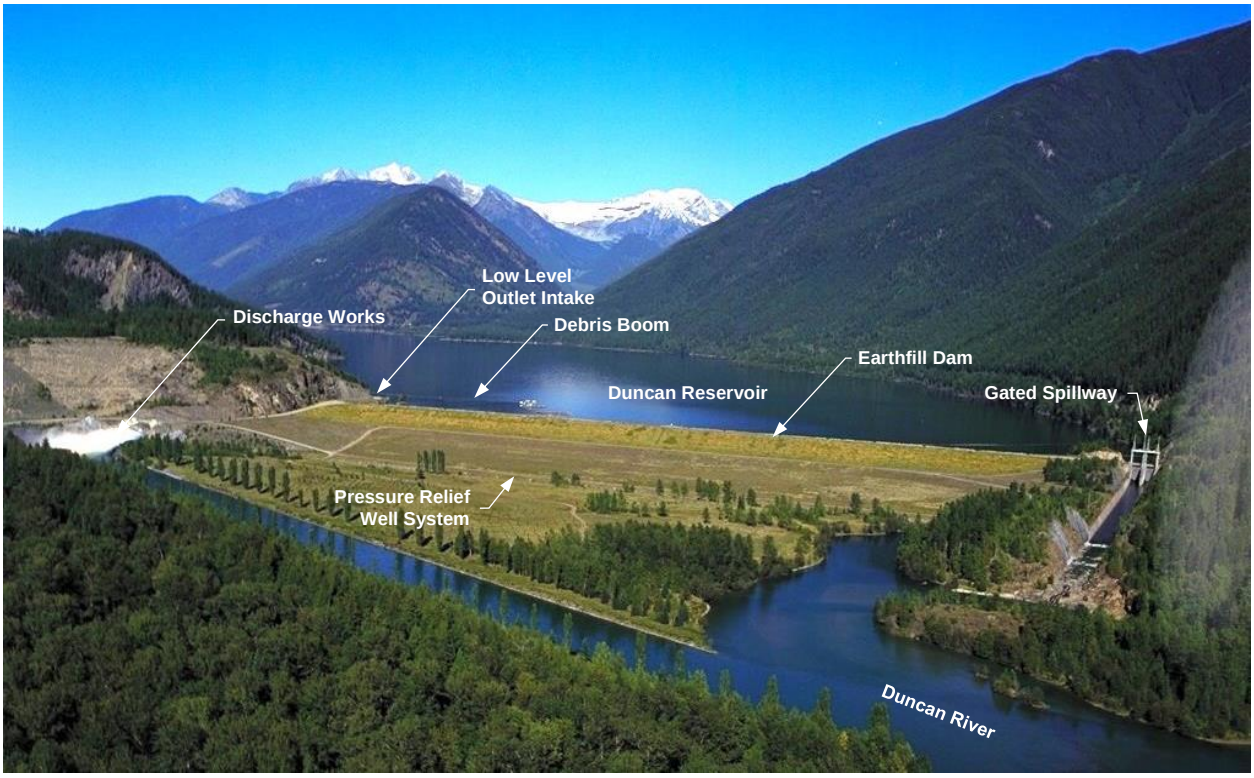
Discussion/Information

Board briefing – DAM SAFETY QUARTERLY REPORT

Duncan Dam was the first of three dams constructed in Canada under the terms of the Columbia River Treaty. The reservoir provides storage for downstream flood control benefits as well as increasing downstream hydroelectric generation benefits in the Columbia River Basin. Fish flow regulation for the lower Duncan River is also provided. Construction work at Duncan Dam began in 1964 and the dam was commissioned in 1967. There is no hydroelectric generation at Duncan Dam.

The main components of Duncan Dam consist of a 38.7 m high and 792.5 m long zoned earthfill dam (crest El. 1907.8 ft.), a gated spillway with a partially lined concrete spillway channel located in the left abutment to pass flood flows and two gated concrete lined rock tunnels (low-level outlets) for normal operational releases and fish flow regulations located in the right abutment.

The dam is founded on a deeply incised canyon infilled by up to 380 m of glacial, inter-glacial and post-glacial soils deposits (compressible deposits of silts, sands, gravels) with steeply sloped rock abutments. The dam was designed and constructed in full knowledge of the difficulties presented by these foundation conditions, which manifested themselves during construction and caused cracks to develop in an area near the left abutment. This led to significant deformations and the need for major design changes being made during construction.



Pressures and seepage through the dam foundation are controlled by an upstream blanket and slurry trench cutoff wall and pressure relief wells. The cut-off wall was originally installed 300 ft. upstream of and parallel to the dam centreline but a small section of the excavation for the cut-off wall collapsed during construction and the cut-off wall was subsequently realigned to 400 ft. upstream of the dam centreline. The pressure relief wells and piezometers near the toe of the dam control and monitor

seepage. The dam is considered to have performed satisfactorily since first filling in 1967, with no significant Dam Safety incidents.

In 2011-2012, the dam's spillway gate systems were upgraded, beginning with the spillway rock stabilization project. The work involved removal of over steepened soil and rock, extensive scaling, rock and soil waste removal, rock bolting, rock mesh and application of steel fibre shotcrete. The early site works also included security fencing, excavation for the new UPS building foundation, and new concrete duct work to interconnect the existing Diesel Generator, the UPS Battery Backup and the distribution power system.

Rock Scaling Activities

Shotcrete Application

Within the spillway gate system upgrade, the gate lifting method was changed from screw hoists to wire rope hoists. The replacement gate towers, hoist house, hoist gear and ancillary equipment were designed for seismic loads corresponding to a Maximum Design Earthquake of 1/10,000 annual exceedance probability and peak horizontal ground acceleration of 0.192 g.

Looking North – Spillway and Hoist House

Looking East – Spillway and UPS Building

Dam performance was initially monitored through visual inspections, surface settlement surveys, and manual readings of piezometers and flows from the pressure relief wells and toe drain. Over the years, a significant number of dam performance monitoring instrumentation, primarily piezometers, have

malfunctioned or been decommissioned, leaving the site under-instrumented relative to other BC Hydro Extreme consequence dams. The Duncan Dam Instrumentation Improvement Project was initiated in 2013 to address the instrumentation issue. The project installed and upgraded instrumentation to determine the seepage through the dam and its foundation and other dam performance parameters. Other upgrades were completed to improve drainage at the toe of the dam and to better collect and convey water from two spillway underdrains through culverts and into the tailwater downstream. The work was completed in 2014.

In the course of completing the Instrumentation Improvement Project, it was discovered that the portion of the dam core nearest to the left abutment was approximately 6-8 feet lower than the design elevation and the other portions of the core. This discovery raised concerns of the core not being high enough to safely route high inflows, such as occur during the spring freshet. A project was launched in 2015 to install a steel sheet pile cutoff wall along the crest of the core along the affected left end of the dam and thereby effectively raise the core of the dam to its design elevation. This cutoff wall installation work was completed in June 2016, prior to that year's freshet. The core upgrade was effectively tested with the prolonged and high inflows at Duncan Dam during the 2018 freshet.

Completed Sheet Pile Wall

Completed Riprap Slope

The upstream face of the dam is protected with riprap which is in a varied condition; in some locations intact while in others it is missing or the rocks have degraded. The upper zone of riprap along the left-most part of the upstream face had been replaced recently in conjunction with the sheet pile core extension, so the riprap at that location is generally uniform and in good condition. A capital project in the 20 year outlook will address this issue.

The performance of the dam body under seismic loading was last assessed in the early 1990's. Since then, the consequence category of the dam has been raised to Extreme and, accordingly, the Maximum Design Earthquake has been increased from an annual exceedance probability of 1/2,475 to 1/10,000 and peak horizontal ground acceleration of 0.192 g. Reassessment of Duncan Dam's performance under these increased seismic demands has been prioritized and queued up within the Dam Safety Investigation Program and is currently scheduled to commence in F2020.

Update on Other Major Dams

Alouette Dam

There are 2 projects (1 capital and 1 investigation) currently underway to address the seismic deficiencies associated with Alouette Dam and Spillway.

Intake Structures Seismic Upgrade

This capital project was initiated in 2016 to address concerns related to the spillway structure's inadequate resistance to earthquake loading by assuring an alternative means of conveying water out of the Alouette Lake Reservoir after a major earthquake. The spillway is expected to suffer damage and not to be functional after a major earthquake. Use of the spillway in such a damaged state could lead to an eventual failure of the dam. Rather than upgrade the spillway to better resist an earthquake, which is both technically challenging and most likely costly, a decision was made to upgrade the power/ tunnel such that it can be relied on to pass the Alouette Lake inflows to Stave Lake following the Maximum Design Earthquake. This will remove the post-earthquake need to pass flows over a damaged spillway, providing time to remediate the spillway.

In F2018, progress on this project was slowed by a delay in carrying out critical field investigations at the tunnel's surge tower and shaft, due to weather conditions and the very difficult access. The team reassessed the planning logistics and successfully carried out the field work in Q1 and Q2 of F2019. This information will be used to complete the feasibility-level designs and Identification Phase, now targeted for completion in October 2019. The lessons learned from this delay in the field investigations will, however, be valuable in understanding and addressing the constructability issues for this project.

Spillway Seismic Assessment Dam Safety Investigation

A Dam Safety Review for Alouette Dam, completed in 2017, identified that upgrades to address the seismic deficiencies in the dam and/or spillway—as described above—have not yet been completed and that interim measures to manage the risks posed by those deficiencies have not, to date, been put into place. The Dam Safety Review identified this lack of an Interim Dam Safety Risk Management Plan to be a "serious omission" and recommended that one be put in place without undue delay, with consideration given to modifying reservoir operation so as to minimize containment against the spillway in other than flood operation.

This Dam Safety Investigation was initiated early in Q2 to address the concerns pointed out by the Dam Safety Review. First, the study reviewed the currently spillway design features, reviewed the previous stability analyses and predicted deformations, carried out additional seepage modelling, investigated additional hydrotechnical scenarios, and identified the failure modes and qualitatively assessed their likelihoods. This work concluded that, although loss of reservoir containment was not likely due to the spillway design and expected stability and deformations, damage to the concrete structure and slabs in a major earthquake is expected. Therefore, the importance of reducing the likelihood of post-earthquake use of the spillway and the effectiveness of the capital project in addressing this risk was confirmed.

Interim measures, including reservoir operational changes, are currently being assessed as to their effectiveness in reducing the probability of overtopping the spillway weir and resultant flows over a

damaged spillway. These assessments will be completed early in Q3 and the selected risk reduction measures will be documented in a draft Interim Dam Safety Risk Management Plan (IDSRMP). Consultation on the draft plan with the Comptroller of Water Rights, First Nations, local authorities, and public stakeholder groups is planned prior to implementation of the IDSRMP.

Mica Dam

Special Investigations Project

The work on Mica under the special investigations project for large embankment dams was initiated in 2015. The overall objectives of this project are to carry out comprehensive performance assessments and develop better understanding of the performance of the subject dams, to develop tools and methodologies for performance monitoring, and to develop future risk management strategies. It is anticipated that a full review of Mica Dam will take 5 or more years to complete.

Work in Q2, continuing from Q1, included:

- Continuation of the work on the development of the 3D CAD and GIS models;
- Developing of the F2019 plan;
- Completion of the laboratory testing of the borrow source materials; and
- Preparation of the overall large scale laboratory soil testing strategy. A contract was signed with Powertech Labs in Q2 to partner in setting up a laboratory, and a kick-off meeting was held.

Rehabilitate Vertical Movement Gauges

During construction of the dam, six vertical movement gauges were installed in the core of the dam. The gauges are no longer used to measure settlement or deformation but have since been used to monitor water levels in the casings, making use of their “leaky” behaviour at casing couplings. Periodic sudden water level drops have been observed in the gauge casings, as well as an accumulation of fine material in the bottom of the casings, suggesting a lack or degradation of sealing at some or all casing couplings and a hydraulic connection through the dam core. This could potentially induce hydraulic fracturing or exacerbate internal erosion within the dam core. These gauges, and the associated issues, are similar to the gauges in the WAC Bennett Dam that were remediated in the past few years.

The Mica Dam project was initiated in F2018, with early work to evaluate the various sealing and instrumentation options. A site investigation to assess the condition and alignment of the casings was completed. Also, in F2018, the project to address the Revelstoke movement gauges was released and combined with the Mica project, for project design and construction efficiencies. No site work has been carried out at Revelstoke.

In Q1, the conceptual design to seal the casings for both the Revelstoke and Mica vertical movement gauges progressed, using the experience from the WAC Bennett observation well design and construction work. As the casings are slightly smaller in diameter than the WAC Bennett observation

wells, the option to include both piezometers and fibre optic cables in the same casing is much more challenging

In Q2, additional field work was carried out to better assess the constructability issues related to this work. As an outcome, the preferred option of installing both a fibre optic cable and piezometer now appears to be promising.

Discharge Facilities Seismic and Reliability Upgrades

The objective of this project is to upgrade the discharge facilities to retain the reservoir and safely pass flows for operational, large floods and post-earthquake conditions, including the ability to drawdown the reservoir post-earthquake if required. In Q2, this project was readied for release, and work will begin in Needs Stage in Q3.

Revelstoke Dam

There are currently three Dam Safety capital projects and one investigation (initiated in F2018) under way, which are described in the following sections. Note that the project to seal/rehabilitate the vertical movement gauges in Revelstoke Dam was described in the preceding section for Mica Dam.

Left Bank – Slope Stabilization

The Left Bank Slope Stabilization Project was initiated in F2017, with the objective to address the risk posed by the '731A Nose' rock slope area on the safety and operation of the powerhouse and the new Penstocks 5 and 6. In addition, further upgrades are required to ensure the safe performance of the 731 Block, which was previously anchored just after construction of the dam and powerhouse. Ongoing rock falls have damaged the anchors' heads and seepage ingress into the heads of the restressable anchors has corroded the strands of the anchors.

In F2018, conceptual designs of works to stabilize the 731A Nose and the slopes above and to protect the 731 anchor heads from rockfall were completed. The options include scaling/bolting of the 731A Nose, excavation of the slopes above and scaling/bolting/meshing and/or shotcreting, and the construction of anchor protection sheds at the 731 Block.

In Q2, work on the project progressed through to completion of a constructability review.

Replace Downie Slide Instrumentation

Downie Slide is a 1.5 billion cubic metre slowly moving rock slide located on the west slope of the Revelstoke Reservoir 65 kilometres upstream of the Revelstoke Dam. Between 1965 and 1993 eighteen inclinometers were installed during four separate field programs for the purpose of charactering the slide, measuring displacements and replacing failed instruments. Historically, at any one time, there have been between five and eleven inclinometers measuring the displacement of the slide. There are currently five inclinometers that are still operational at the slide. It is forecasted that these inclinometers will have been disrupted by the slide activity within the next five years. To proactively measure slide displacement, an instrument replacement strategy is required to define the degree/level of monitoring. Incorporated in this strategy is a requirement to evaluate alternative

displacement monitoring capabilities that could address the high cost of conventional techniques, both from an installation and operation perspective.

This project was initiated in F2018 and development of the identification (conceptual design) phase work plan was completed, which includes both replacement of existing inclinometers, combined with the evaluation of alternative slope monitoring options. Funding for the conceptual design stage was also approved in F2018.

Conceptual design for the project was completed in Q2 and a request for funding of the Feasibility Design Stage is scheduled for October 2018. The field trial of the ground-based GPS system continued, with completion targeted in Q3.

Spillway Chute Condition Assessment

Small movements of the Marble Shear Block have produced cracking of the spillway concrete slab, and although unrated, this deficiency has been monitored for some time. The cracking has become more pronounced with time and, together with the observation that one of the underdrains is now flowing during spillway use, has prompted a review of the design and the rating of the deficiency. A screening level assessment in F2018 concluded that generally, the spillway design at Revelstoke appears to be consistent with modern spillway design practices, considered satisfactory, and no immediate concerns were identified. Nevertheless, the chute condition and Marble Shear Block drainage will continue to be closely monitored.

WAC Bennett Dam

There are six ongoing dam safety projects as follows:

Spillway gate reliability

The project will upgrade selected electrical and mechanical components of the three spillway gates. The project is currently in Implementation Phase. Construction is expected to start in February 2019 and be completed by October 2019.

Special Investigations Project, Long-term performance of the dam core

A special investigations project for large embankment dams was initiated in 2011, starting with the WAC Bennett Dam. The overall objectives of this project are to carry out comprehensive performance assessments and develop better understanding of the performance of the subject dams, to develop tools and methodologies for performance monitoring, and to develop future risk management strategies. This has been a multiple year project, and the progress has been reported previously.

In Q2, work continued in assessing the “air theory” concept to explain the observed behavior of WAC Bennett Dam during its first 30 years of operation. The pore pressures in Bennett Dam’s core have been monitored since construction and currently, with the dam approximately 50 years old, the readings are as expected. About 20-30 years after construction, however, the measured pore pressures were higher than simple saturated flow theory would predict. One theory to explain this behaviour—the so-called “air theory”—models the air trapped within a dam core during construction and how it slows down the dissipation of pore pressures within the core, particularly during early to

mid-life of the dam. A consultant is performing this work and is presently completing the report, including recommendations for next steps.

Work continued on the development of the 3D CAD model, specifically to include the earthfill wrap-around section and its contact with the concrete portion of the spillway, which has proved to be challenging to implement in CAD.

Finally, anticipating the need for large volumes of dam fill materials in preparation for additional laboratory testing, a permit was obtained to collect large samples from the South Moraine area (the original borrow area for the WAC Bennett Dam). The soil samples will be collected in Q3.

Embankment Dam Instrumentation Upgrade

Following from the findings of the special investigations performance assessment work, an evaluation of the failure modes and a review of the existing instrumentation, sufficient characterization of the dam have been completed to determine future dam instrumentation requirements. A capital upgrade project to install new dam instrumentation was initiated in F2018. The objective of this project is to identify and install/upgrade dam instruments to ensure that, coupled with the existing monitoring network, the dam is and will continue to be adequately monitored. A plan was developed to systematically identify the gaps in the instrumentation network and to identify both conventional and potentially new, non-intrusive type methods of dam monitoring.

In F2018, four workshops were organized in order to share background information, identify monitoring deficiencies using failure modes and key performance indicators as the basis for evaluation, and to refine the scope of work for the project. A user requirements document was prepared to guide the assessment, and development of a 3D seepage model of the dam was begun.

In Q2, the 3-D seepage model of the dam was completed. These results will be used to better understand the flow regime and as input to the design for the weir upgrades. Additional work to review previously collected cross-hole shear wave information and assess its usefulness in monitoring dam core performance changes continued.

Condition of the riprap layer protecting the upstream face of the dam

After a 20-year Dam Safety initiative and after 8 years of this project, the bedding and riprap construction on the dam face was successfully completed in late F2018.

In Q2, the re-paving of the road across the dam crest, including the installation of road barriers, was completed. Reclamation of the Sand Flat Quarry was completed. A project celebration event was held at site in August, to commemorate the successful completion of this work and to acknowledge the extraordinary efforts of the project team. Project documentation and completion is continuing and project closure is planned in F2020.

Seal Low Level Outlets

A long term strategy was previously developed—as part of a separate study—to assess the best alternative for the future of WAC Bennett Dam's Low Level Outlets, constructed in the original diversion tunnels and left in place since construction. The following options were considered:

maintaining the status quo, refurbishment for additional discharge capability, re-purposing for additional generation, and decommissioning, either permanently or with the option to re-open the LLOs at some time in the future. Based on this study, the recommended alternative was to permanently decommission the Low Level Outlets, which was forwarded to and accepted by the Comptroller of Water Rights. The ensuing capital project was started in F2018.

The funding for the conceptual design stage was approved in Q1 of F2019. Site inspection planned for the Conceptual Design stage was carried out in Q2, and the findings of the inspection have been documented. Preparation of the Conceptual Design Report is underway.

Recommission/Seal Sluice Gates

As part of original construction, the WAC Bennett Dam included nine sluiceways and slide gates (sluice gate) located under the radial gate spillway ogee block, on the right abutment. The last known operation of any of the sluice gates was in 1987, when some problems were noted. Subsequent inspections have revealed further deterioration of components of the sluice gates.

Due to the potential risk of uncontrolled release of water if the gates are left in place in an unaltered, unmaintained and continuously deteriorating state, this project was initiated in F2018 to develop a long term strategy for the future role of the sluice gates. Also included in this project is to determine the future need for and possible upgrades to the leaky spillway stoplogs. Work completed in F2018 included site inspections (including visual and remotely operated underwater vehicle inspection of the sluice gates and visual inspections of the stoplogs), decision framework meetings to assess the functional requirements of the sluice gates and the stop logs, and to develop options.

In Q2, the leading alternative of sealing the sluices from the downstream end was selected, to be carried into the Feasibility Design. To carry out this construction work, the need for competent stoplogs is not required as the existing sluice gates can provide the necessary function. A recommendation will be made to upgrade the stoplogs, possibly by initiating a separate project with its own business case and released in priority order.

Ruskin Dam

After a 20 year Dam Safety initiative, and 11 years of this project, the construction of the upper part of the dam (including commissioning of the new gates) was completed in F2018.

In Q2, work to address needed improvements in spillway gate reliability—including planning for the procurement of a permanent diesel generator and a battery inverter as auxiliary power sources, and the reconfiguration of hydraulic piping to allow the hydraulic power units to serve as backups—continued. Documentation of the construction in record drawings and the construction report continued. Work also continued to re-assess the dam using the comprehensive 3-D finite element model of the dam, under development since 2014. This work is targeted for completion in F2019, at which time the question of the need for additional anchors will be concluded.

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Board briefing – DAM SAFETY QUARTERLY REPORT

Terzaghi Dam – Spillway Chute

Deficiencies associated with the Terzaghi spillway chute were documented in the F2018, Q3 report, which concluded that the issues were a high priority. In F2018, a plan was prepared to gain partial access to the chute in order to carry out a limited inspection in June of 2019.

Access to the upstream end of the spillway—that portion between the headworks structure and the spillway bridge only—was enabled by rock scaling of the slope above, which sufficiently reduced the risk of rockfall to allow entry into the chute by BC Hydro personnel for cleanout and inspection. This portion of the spillway, and specifically an area on the left-hand side of the spillway adjacent to the dam's core, was targeted for first inspection due to concerns that a lower rock surface elevation might present a seepage path into and through the dam's core in the event of localized chute failure at that location.

This rock scaling and associated inspection by BC Hydro Engineering provided beneficial information to the recently initiated project to provide permanent safe access into the spillway and has provided confidence to the view that—in the upstream portion of the rock face, at least—there is a relatively straightforward rock meshing solution available. Design concepts for the downstream portions are still being developed.

Activities included in the inspection of the upstream portion of the spillway chute were: visual observations and photographs; basic dimensional checks of the spillway and measurements; mapping of damaged areas; Schmidt Hammer testing; core drilling for concrete and bedrock samples in the spillway chute; local reinforcement scans; drain cleanout inspection and drain flushing. The inspected portions of the chute indicate good materials and construction, fair to good condition considering the spillway's age, and free-flowing drains. No immediate risk to the structural integrity of the spillway's upstream portion was observed.

Engineering's site investigation report is still in preparation in Q2, but preliminary findings have been communicated to Dam Safety, as follows. The rock under the spillway's concrete slab is competent: strong, not weathered, only slightly fractured near the surface consistent with the original excavation processes. There was very good observed contact and bond between the rock and the concrete slab, to the point where separating the rock and concrete for testing required breaking of the concrete rather than the interface. These conditions were found at all cored locations, including the targeted point adjacent to where the exposed rock elevation is lowest.

As a result of these findings, the concerns initially communicated in the F2018 Q3 report have been substantially allayed. There is no longer a heightened concern that deficiencies in the spillway's design could lead to a failure of the dam in the event of a spill. Recognizing that only the upstream portion of the spillway has been inspected and that there are verifiable deficiencies in the spillway's design relative to modern practices, however, there does remain some potential for significant damage to the spillway and associated financial loss resulting from a spill. Plans for future site investigations and drain maintenance on the lower spillway and analytical investigations of the impacts of the design deficiencies will be developed in Q2 through Q4. Until such time as the aforementioned investigations are complete and/or all identified concerns have been dispelled, spillway operation will be accompanied by enhanced surveillance.

Campbell River System

The high-level strategy for long-term risk management for the Campbell River System was described in a previous Executive Summary (Q3 of the F2014 report), and an overall update was provided in Q3 of the F2017 report. There are three ongoing dam safety projects:

Strathcona Dam – Upgrade Discharge

This project was initiated in 2015. The Identification Phase of this project determined the feasible alternatives for the new Low Level Outlet, including the sizing of the new discharge and options for safe discharge downstream through the Campbell River system. The spillway upgrade project (originally released as a separate project in F2016) was combined with the Low Level Outlet project in F2017. Work completed to date includes:

- Selection of the preferred alignment of the new Low Level Outlet on the right abutment;
- A decision to combine the spillway and low level outlet functionality, which provides dam safety risk reduction with improved reliability at the lowest cost; and
- Key design decisions relating to the Low Level Outlets, including selection of the number (two) and type of gates (vertical lift gates), the type of hoists (wire rope), and the selection of an open channel over the tunnel option.

In Q1 of F2019, Conceptual Design of the conversion of the existing gated spillway to a free overflow spillway neared completion. A key decision input to the design was the decision of whether to raise the dam crest in order to accommodate routing of the dam's Probable Maximum Flood. It was determined that by maintain the current dam height by either replacing or repairing the existing lock block and membrane flood wall, the new configuration of spillway and Low Level Outlet could safely route floods having return periods of significantly greater than 10,000 years, meeting the "risk-informed" performance targets in the CDA Guidelines. Due to the costs and marginal flood benefits associated with a dam raise, the project is moving forward on the basis that there will be no change to the current dam height, and this design decision has been presented in person and in a detailed letter to the Comptroller of Water Rights.

In Q2, work continued on the feasibility design of the new low level outlet and spillway. The first Strathcona Dam Advisory Board meeting was held in August, and their draft report has been issued. In general, the Advisory Board agrees with the approach taken in this project and has made some recommendations on the design options, which are currently being assessed by the project team. In addition, the terms of reference for the reliability assessment work were prepared, and a consultant has been contracted to carry out this work.

Ladore Dam

The project has completed Conceptual Design, with the decision made to replace the existing gates, hoists, tower and deck. The project is currently in Feasibility Design, with design of the new vertical lift gates, the new hoist towers, deck and new control building on the right abutment continuing. In Q1, the site investigations program, including the drilling of three holes into the concrete and underlying rock foundation, was completed.

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The first Ladore Dam Advisory Board meeting was held in August 2018, and their draft report has been issued. In general, the Advisory Board is in agreement with the proposed work of upgrading the gate systems, but has made some recommendations on analyses and designs. The project is currently reviewing these comments and recommendations and their impacts on the work going forward.

John Hart Dam

The project is currently in the Feasibility Design Stage. Work to date has identified preferred alternatives for the North Earthfill Dam, the Main Concrete Dam, the Middle Earthfill Dam and the existing Intake Dam. Designs are also continuing on converting the non-overflow section of the Concrete Dam into an overflow spillway.

In Q1, in-reservoir drilling was started, with the findings of the drilling expected to be available in time for the Advisory Board scheduled in mid-August. This will address one of the key Advisory Board's recommendations from the previous meeting, which was to obtain site-specific geotechnical information from the reservoir to confirm the upstream berm design details before proceeding to Preliminary Design. Drinking water quality issues associated with the planned reservoir drawdown during construction will need to be managed by the project. A recently completed engineering study has evaluated potential water quality mitigation options and has concluded that a temporary treatment facility is technically feasible. The project team is preparing an update and will seek a direction from management regarding a mandate for discussions and negotiations with the City of Campbell River about water quality mitigation.

In Q2, the field investigations neared completion and the project team is now assessing the impacts of this new information on the site characterization and design. The 4th John Hart Dam Advisory Board meeting was held in August where the findings from the in-reservoir field investigations were presented. The Advisory Board's draft report has been issued. In general, the Advisory Board is in agreement with the project's direction.

Overall coordination of the Campbell River System

As the three projects progress, additional coordination work will be undertaken by Dam Safety, Project Delivery, Engineering, Supply Chain, Regulatory, Environmental, Indigenous Relations, Operations and others, as required, to ensure that the designs, construction, Supply Chain strategies, etc. will be strategically optimized and coordinated. The John Hart Dam Advisory Board's terms of reference has been expanded to include the Strathcona and Ladore Dam Safety Projects to further ensure coordination. The Advisory Board will now be referred to as the Campbell River Advisory Board and the first combined meeting was held in Q2.

Salmon River Diversion

The dam removal/river restoration was completed in F2018 and work continued on post-decommissioning documentation and procurement of a Certificate of Compliance and Land Tenure.

New Issues

Hugh Keenleyside Dam

During a period of low tailwater level, fine sand was observed immediately downstream of the reverse filter berm that was constructed in 2015. At this time, it is unclear whether the presence of this material indicates poor performance of the 2015 filter berm or is the result of another process. This area will be evaluated during the weekly and semi-annual inspections for evidence of potential deteriorating conditions.

Wilsey Dam

Ongoing deterioration of the concrete in the Main Dam and Plug Dam at Wilsey has progressed to the point where this issue has been changed from a Non-Conformance Maintenance (NCM) issue to an Actual Normal deficiency. The observed deterioration is beginning to undermine the post-tensioned anchor caps. Progression of this deterioration will be monitored in weekly inspections. Wilsey Dam will be given additional attention in developing next year's civil maintenance plan and a structural assessment will be incorporated into the Investigations program.

GATE MAINTENANCE AND TESTING

During the period of July to September 2018, 60 scheduled gate tests at 23 sites were carried out. No gate system failed to operate on demand during testing. In six other cases, while gates did operate on demand, certain individual components of the gate system malfunctioned or were found to be in unacceptable condition.

As of the end of September 2018, operational restrictions were in place on two out of 109 flood discharge gates due to known deficiencies (reduced from nine in the previous quarter).

A total of 25 corrective maintenance issues were identified through ongoing testing and maintenance from March to June 2018. A total of 32 new and previous issues were addressed in the same period, for a reduction of 7 overall in this reporting period. There were 112 corrective maintenance issues outstanding at the end of September 2018; 22 more than in September 2017.

CIVIL MAINTENANCE

As of the end of Q2, 19 of 33 planned civil maintenance projects were substantially complete, with a total spend to the end of the second quarter of $2.3M. The following projects were completed in Q2:

- Aberfeldie Dam spillway repairs;
- Revelstoke Dam spillway repairs:
- WAC Bennett Dam spillway inspection:
- Strathcona Dam flume inspection/repair; and

- Walter Hardman penstock inspection.

In Q2 the $450K Seven Mile Dam Spillway Repair project started and is expected to be complete in October 2018. Access for this spillway repair project posed significant challenges, as shown in the photo below.

Work continues on the Civil Preventative Maintenance (PM) Program. The "Package 1" assets, which include booms and non-water-to-wire tunnels, are in implementation across the fleet. A Passport audit of the Civil PM Package 1 implementation was completed in Q2 and some gaps were identified. The Civil PM team is working on an action plan to address these gaps.

Development of the maintenance standards and maintenance instructions for Packages 2 and 3, which include other assets such as penstocks, spillways, canals, and foundation pressure relief drains, is ongoing. The scheduled release of Packages 2 and 3 is at the beginning of F2020.

EMERGENCY PREPAREDNESS AND PUBLIC SAFETY

Emergency Preparedness is managed by the Strategic Emergency Management team. Dam Safety reports on the updating of emergency plans for compliance with the BC Dam Safety Regulation as part of annual compliance reporting to the Comptroller of Water Rights.

Public Safety is managed by the Public Safety team in Safety Engineering. Dam Safety reports on Public Safety activities related to dams during the Dam Safety Reviews.

Please refer to other reports for quarterly updates on Emergency Preparedness and Public Safety around dams.

COMPLIANCE WITH PROCESSES AND REGULATION

The Clowhom OMS Manual and the Comox Dam Safety Review were submitted in August 2018. A request to alter the John Hart Intake Dam was submitted in September 2018.

Inspections

409 out of 411 (99.5%) scheduled inspections were completed during Q2. Two weekly inspections were missed in July. One inspection was missed at Cheakamus Dam due to a misunderstanding by a newly trained inspector and one was missed at Terzaghi Dam due to a miscommunication between two crew members. The Dam Safety Engineers reviewed the importance of the inspections with the responsible Operations managers and local crews.

Dam Safety personnel continue to attend planning meetings with plant staff on a monthly basis.

An initiative for F2019 has been for the Dam Safety Technologists to perform three checks/reviews of the instrumentation data plots to ensure continued accuracy of the data being collected. Through the first two quarters of the year, 369 of the targeted 390 reviews have been performed, with continual improvement observed each successive month.

Dam Safety Reviews

Dam Safety Reviews are a regulatory requirement carried out at minimum intervals of every five to ten years at High, Very High and Extreme consequence dams. The final report for Comox Dam was received in Q2 and the report for Revelstoke Dam is currently in process of being finalized.

Site visits and staff interviews were held for the Hugh Keenleyside, Kootenay Canal, WAC Bennett and Peace Canyon Dam Safety Reviews in Q2. The Walter Hardman Dam Safety Review is scheduled to begin in Q3 with the majority of work taking place in F2020.

VULNERABILITY INDEX: UPDATE

Changes in Vulnerability Index for actual and potential deficiencies, as outlined in Figure 1, are tracked on a quarterly basis and shown on Figures 2 and 3. This is an indication of the changes in the understanding of the dam safety risk profile. In Figure 3, the total index is shown (sum of actual and potential deficiencies), as well as separate plots for decreases and increases in the total index. Decreases are due to remediation projects as per the Capital Plan, completed repairs and corrective maintenance, and resolution of issues via Performance Investigations. Increases in the index are due to the recognition of new issues. Existing issues are re-examined on a regular basis and re-rated as required.

The baseline for the separate plots of decreases and increases to the Vulnerability Index has been set at the time of the development of the first 10 year capital plan.

Discussion/Information

Board briefing – DAM SAFETY QUARTERLY REPORT

Notable changes in Vulnerability Index in Q2 are:

- A Vulnerability Index addition of 1.0 (Potential Normal deficiency) at Hugh Keenleyside Dam following the observation of fine sand deposited immediately downstream of the reverse filter berm that was constructed in 2015.See the discussion under “New Issues”.

- A Vulnerability Index addition of 1.98 (Potential Unusual deficiencies) at Cheakamus Dam as a result of updated analyses carried out in the Dam Safety Review. The penstock supports are assessed to have inadequate seismic withstand. The Main Dam, Earthfill Dam and Saddle Dam No. 1 are assessed to have inadequate stability under the Probable Maximum Flood.

- A Vulnerability Index addition of 2.58 (Actual Normal deficiency) at Wilsey Dam as a result of ongoing deterioration of the concrete in the Main Dam and Plug Dam. See the discussion under “New Issues”.

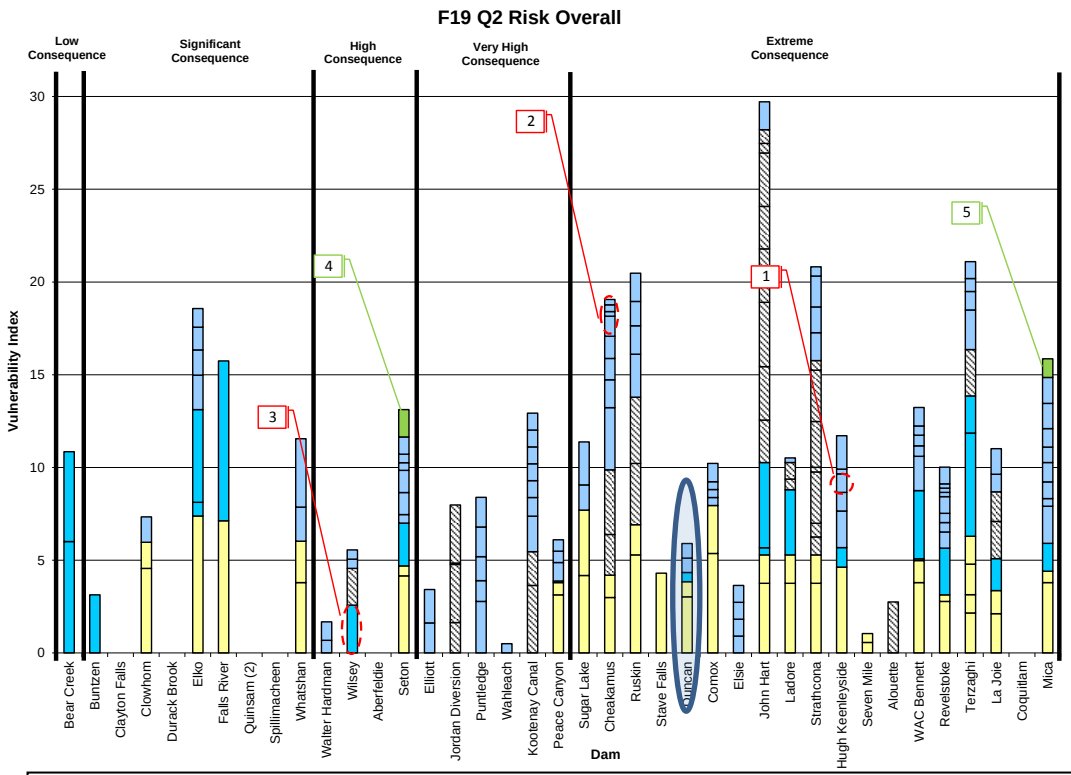
- A Vulnerability Index reduction of 1.47 at Seton Dam due to the successful concrete repair of a joint in the aqueduct and repairs to the canal concrete lining.

- A Vulnerability Index reduction of 1.04 at Mica Dam due to completion of a seismic stability assessment of the Intake Tower which indicates that the withstand of the tower is satisfactory.

The result is a net increase in the system-wide Vulnerability Index of 3.1.

Board briefing – DAM SAFETY QUARTERLY REPORT

Figure 1 - Dam Safety: Overall Risk Profile



Legend and Summary of Changes

Increase in Risk

Hugh Keenleyside Dam *– Fine sand deposits observed downstream of the reverse filter berm*
Cheakamus Dam *– Potential instability of Main Concrete Dam, Earthfill Dam and Saddle Dam No. 1 under Probable Maximum Flood and potential instability of penstock under seismic loading*
Wilsey Dam *– Ongoing deterioration of concrete in the Main Dam and Plug Dam*

Reduction Risk

Seton Dam *– Repairs to the canal lining were completed in 2017 (not previously reported)*

Mica Dam *–Seismic stability of the Intake Tower has been assessed and found to be satisfactory*

Quarterly Featured Dam

A – Actual deficiencies have been shown to exist.
P – Potential deficiencies require further investigation.
N – Normal Load conditions; associated with daily or short-term operations.
U – Unusual Load conditions: associated with flood and earthquakes

Consequence classifications reflect current BC Dam Safety Regulations.
Dam order reflects generally increasing downstream consequences

NOTES:

- Vulnerability Index (Rating) is a qualitative assessment of future dam performance from all causes – the higher the rating the higher the likelihood of poor performance.
- 33 dam sites as identified have reportable risk at present
- This Risk Profile represents only currently known and rated issues. Changes do not necessarily indicate a physical change to BC Hydro assets that increase or decrease risk; rather they often represent a change in knowledge and understanding of the risk. Additionally, many known deficiencies (those without a direct impact on potential dam failure) have yet to be rated.

Figure 2 – Change in Actual and Potential Vulnerability Indices

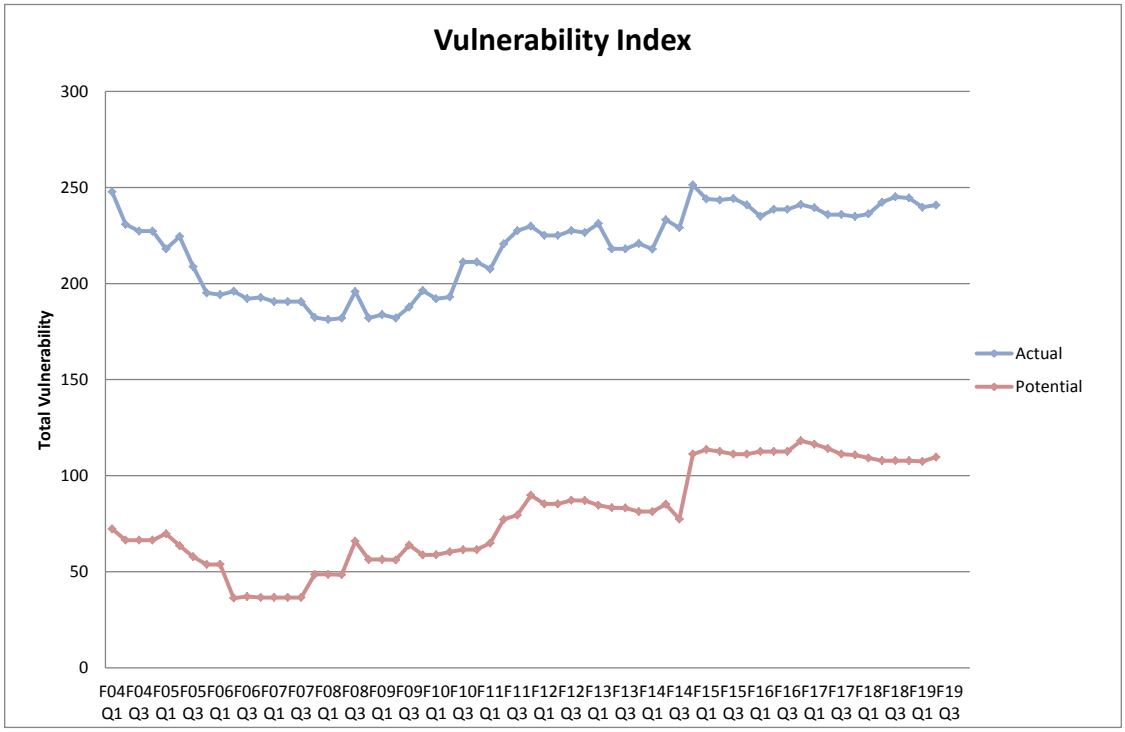


Figure 3 – Change in Total Vulnerability Index Components