BC Hydro
Power smart

Discussion/Information

Board briefing – DAM SAFETY QUARTERLY REPORT

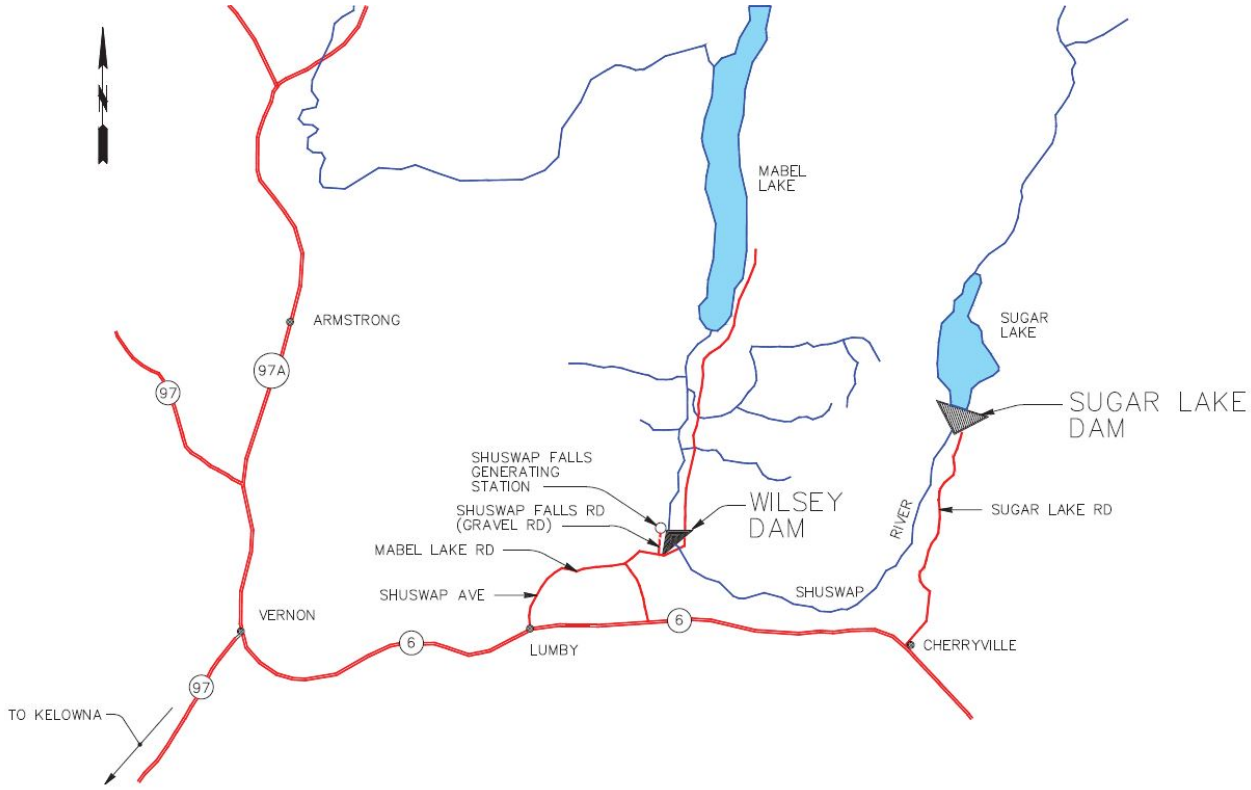
Executive Summary

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 January 1, 2017 to March 31, 2017, 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 decrease in the risk profile this quarter due to completion of a stability model for Peace Canyon Dam and completion of the Ladore Dam stability assessment under seismic loading.

Quarterly Featured Damsite – Wilsey Dam

Wilsey Dam is a High consequence dam located on the Shuswap River, approximately 40 kilometres by highway east of Vernon and 29 kilometres downstream of Sugar Lake Dam. The consequence of Wilsey Dam is based on the potential environmental impacts of sediment release if the dam were to fail. The Wilsey Project consists of a main arch dam, an overflow spillway arch dam, two power intakes, tunnels and penstocks leading to the two unit powerhouse. The primary purpose of Wilsey Dam is water impoundment for power generation at the Shuswap Falls Generating Station, located approximately 140 metres downstream of the dam. There are two water licences for power purposes at the Shuswap Generating Facility that expire on December 31, 2018. One is for partial diversion of the water and one is for the storage at the Wilsey Headpond. A project is underway to submit the initial application for Shuswap water licence renewal in October 2017.



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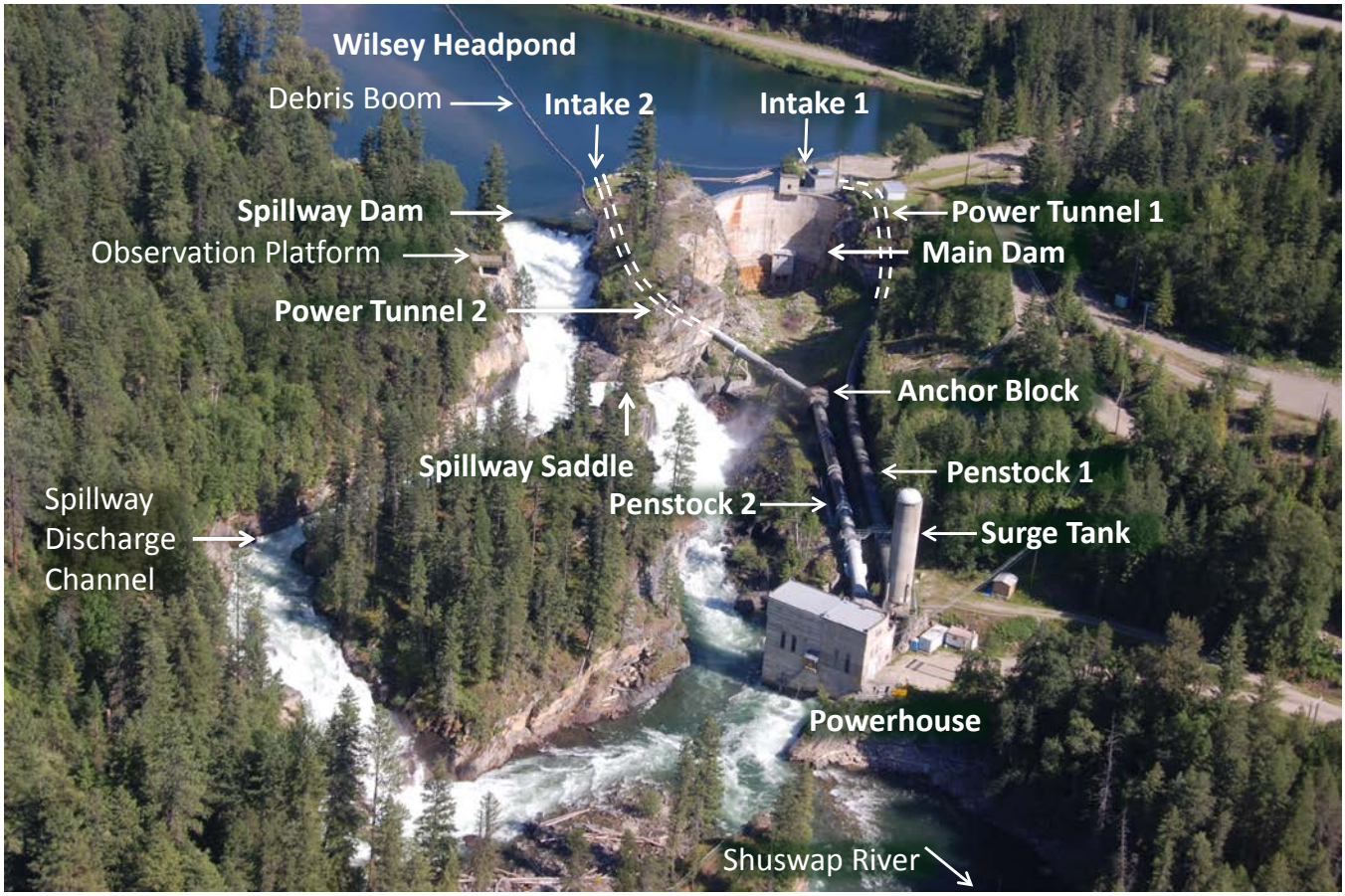
The Wilsey Project was originally constructed in 1929 by the West Canadian Hydro-Electric Corporation and was acquired by the B.C. Power Commission in 1945. The main dam and the spillway dam are the only arch dams in the BC Hydro portfolio.



Main Dam

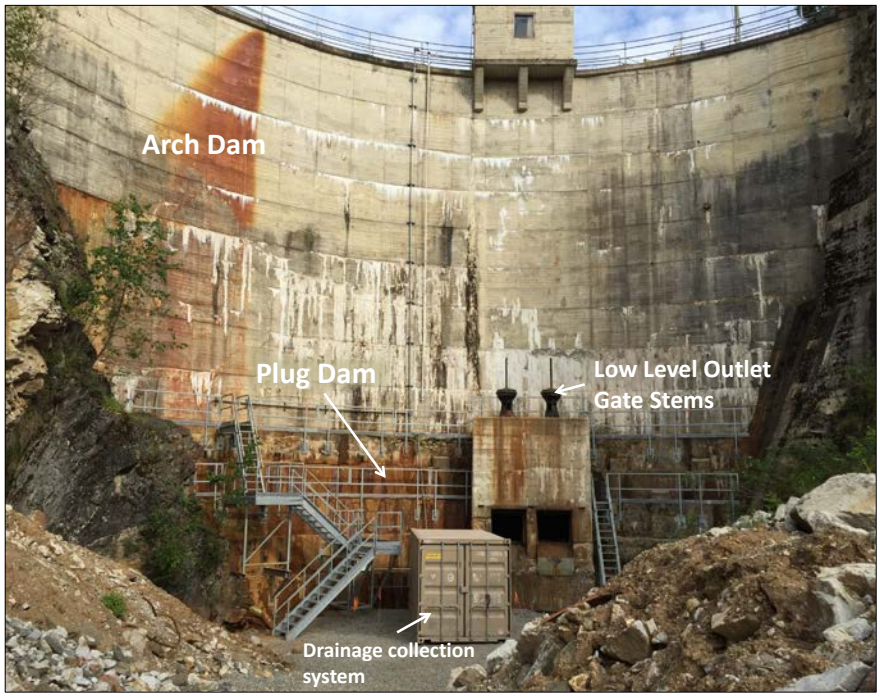
The main dam at the Wilsey Project consists of two separate structures located in a narrow, steep walled canyon: a concrete arch dam and a plug dam at the toe of the arch dam. The arch dam is approximately 25 metres high, 1 metre wide at the crest and 2 metres wide at the base. The 13 metre high plug dam was constructed at the base of the arch dam after the foundation of the arch dam failed during first filling. In 1992, fourteen post-tensioned anchors were installed and drains were drilled to improve the stability of the plug dam.

The original arch dam was constructed with two low level outlets which were subsequently extended through the plug dam when it was constructed. Originally, the low level outlets consisted of two formed concrete conduits, 1.22 metres square, with steel slide gates at the upstream end of the conduits. The gates were operated from the gatehouse on top of the dam with a monorail hoist. In 1941, new gates were fitted to the downstream ends of the low level outlets and the original gate configuration was abandoned. These downstream gates were replaced in 1952 with slide gates and conduit liners.

A flood event in 1948 introduced a large volume of sediment into the Wilsey headpond and from that time forward, sediment became a significant operational issue. The low level outlets were used

periodically to assist with desilting until 1972, which is the last time they were operated. By the late 1980s they had fallen into disrepair and were completely blocked with silt upstream. Their use to assist with desilting had also ceased due to environmental / fisheries concerns about introducing sediment into the Shuswap River. In 1990, steel inlet bell mouths were installed at the entrance of each low level outlet. Steel cover plates were then bolted to the upstream bell mouths of the low level outlets rendering them inoperable. Sediment is now dredged from the reservoir near the intakes as required.

A project was carried out in F2016 to provide monitoring of foundation drainage system, re-establish monitoring capability in the left abutment and improve access to the toe of the arch dam and the top of the plug dam.



Wilsey Dam view from the downstream following F2016 work

Post-tensioned anchor head

Steel and woodstave penstocks

Water Passages

There is a free overflow spillway at Wilsey Dam, located to the right of the main dam. The spillway dam is approximately 3 metres high and 34 metres long. Until recently, flashboards were installed on the crest of the spillway dam near the end of summer to raise the headpond level by another metre and then removed prior to freshet.

There are two separate intakes for the two generating units in the Shuswap Falls powerhouse. The water passage for Unit 1 was originally constructed in 1929 and consists of a tunnel excavated through the left abutment, woodstave penstock, surge tank and concrete conduit on the left bank of the original river channel. The woodstave penstock was rebuilt in 1970 with new woodstaves. The Unit 2 water passage was originally constructed in 1942 and consists of a power tunnel through the right bank, steel penstock and concrete conduit. The original Unit 2 woodstave penstock and surge tank were replaced by the current steel pipeline and hollow-cone bypass valve in 1993.

Unit 1 is currently out of service and has been for several years. While Unit 1 is down, Penstock 1 is kept fully charged during the summer months to prevent the woodstaves from drying out. Intake Operating Gate 1 is closed at the beginning of the winter to drain Penstock 1 and is opened in the summer to fill it. There is a possible vulnerability should Penstock 1 start to leak or deteriorate in a fully charged condition as it is unknown if the intake operating gate can close under full-flow conditions, as designed. The gate is not currently tested but it is operated at least once per year.

Update on Other Major Dams

Mica Dam

A special investigations project for large embankment dams was initiated in 2015. The overall objective of this project is to develop tools and methodologies for performance monitoring of BC Hydro dams. At Mica, the objectives are to carry out a detailed performance assessment of the dam by developing, testing and verifying numerical analyses of the dam behaviour. The work will provide a good understanding of the current condition of the dam as well as a set of monitoring and response systems that can be utilized for dam safety management decisions and activities.

Work continued in Q4 on development of a comprehensive three-dimensional computer model of the foundation. This is the first step in a complete design review to be undertaken over the next 3-5 years. Also in Q4, the report by the Expert Engineering Panel covering their first meeting (held in Q2) was issued. In the opinion of the Expert Engineering Panel, Mica Dam is designed and constructed in such a way that it safely controls all current seepage flows, however there is a potential issue in a post-seismic situation at the very top part of the dam. The Expert Engineering Panel provided a number of recommendations for the scope of the design, construction and performance review that BC Hydro plans to perform.

Revelstoke Dam

The final remaining project work addressing the Marble Shear Block is nearing completion. The installation of two new in-place inclinometers in the Marble Shear Block was completed in Q3. The LiDAR survey and project documentation are targeted for completion in Q1 of F2018.

The Project Construction Report for the Left Bank instrumentation was completed in Q3, and project completion documentation is targeted for completion by Q2 of F2018.

WAC Bennett Dam

There are five ongoing dam safety projects:

Condition of the spillway (deterioration of the spillway chute concrete surface)

The construction work on the sloping part of the spillway chute has been successfully completed. In addition, remaining minor repairs to the flat part of the chute were also completed. With the completion of the construction work, the spillway chute was returned to service. Work will continue into Q1 of F2018 to finalize the construction report, including the record drawings.

Spillway gate reliability

The project will upgrade selected electrical and mechanical components of the three spillway gates. The project is currently in Definition Phase, and engineering work is continuing.

Long-term performance of the dam core

The overall project objective is to better understand the current condition and behaviour of the dam and to provide improved monitoring and response systems. In Q3, the comments received from the Expert Engineering Panel were incorporated into the WAC Bennett Dam performance assessment report. Work in Q4 continued with:

- Planning activities for F2018 and F2019, and
- Continuing the work on performance assessment.

Casing Upgrades

This project was initiated to address the leaky open casings in the core, while retaining their usefulness where applicable. In Q3, the contractor was successful in unplugging the cross-arm casing by over-reaming the seismic hammer which then fell to the bottom of the casing. The plan is to grout up the bottom of the casing in 2017 and retain the use of the cross-arm casing for future geophysical testing, pending the development of a seismic hammer small enough for use. In Q4 work continued with:

- Connecting the temperature monitoring system installed in the observation wells to the data collection network, and
- Finalizing the designs for the grouting of the remaining drill holes planned for spring/summer of 2017.

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

The contractor mobilized to site in Q2 of F2017. The planned first year quarry development was completed in Q4, all the riprap and bedding materials required for placement on the dam during the first construction window were hauled to the main stockpile area and the Contractor started the in-dry placement of the riprap materials.

Ruskin Dam

In January 2017, new spillway gates 3 and 4 were placed in-service and the temporary bulkhead was successfully re-attached to the dam for the next phase of construction. Work is began on construction of the final spillway gate 5 in Q4.

In Q4, work commenced on the next stage of the Ruskin Dam Anchoring study which involves additional finite element analyses for use in the assessment of additional anchors that may be required to stabilize the structure during an extreme seismic event. The Advisory Board met in Q3 and a draft report has been received . The report will be finalized in Q1 of F2018.

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 last quarter. Recent and ongoing work at the three sites is as follows:

Strathcona Dam

Work continued in the conceptual phase on the design of the Low Level Outlet. A leading alternative has been identified on the right abutment, and includes combining spillway and low level outlet

functionality, which will make it possible to significantly reduce the level of effort in upgrading the current spillway for post-seismic operability. Work in Q4 continued with completion of a conceptual design cost estimate, and with starting the work on the design basis and design plan documents for the feasibility design stage.

Ladore Dam

The conceptual design report for the spillway seismic upgrades was finalized in Q4. Preparation of the feasibility design plan is in progress.

John Hart Dam

A field investigations program was carried out in Q3 to obtain additional soils information required to improve stability models, as was suggested by the Advisory Board. This information is required to develop the upstream remediation options at the Middle Earthfill Dam. In Q4, the obtained stratigraphic information was used to update the stability models. Re-scoping of work to complete feasibility design, including incorporating comments from the Advisory Board, was also completed. Laboratory test program for determining soil strength parameters and feasibility design of dam upgrade are on-going into Q1 of F2018.

Salmon River Diversion

The Salmon Diversion Dam and Canal divert water, when available and/or required, from the Salmon River Headpond into the Lower Campbell Lake Reservoir. The Diversion Dam is a Low Consequence rockfill timber crib dam. The dam has deteriorated over the last several years, and it is now considered to be in Fair to Poor condition. Operation of the diversion canal is limited in capacity because of the poor condition of the concrete lining. Both upstream and downstream fish passage facilities perform poorly, and BC Hydro has previously committed to improving fish passage at this site. A project was initiated to address the fish passage and other issues at this site, but by the end of Definition phase, the alternative of refurbishing the facility was deemed not viable on the basis of marginal economic benefit and impact of maintaining an ongoing environmental footprint. Thus, a new project has been initiated to decommission the dam and reinstate natural flow and fish passage. The feasibility design report and cost estimate for decommissioning were finalized in Q4. Also in Q4, an application to cease operations was filed with the British Columbia Utility Commission and the preliminary design report was submitted to the Comptroller of Water Rights. Decommissioning of the facility is expected to take place in the summer of 2017.

GATE MAINTENANCE AND TESTING

During the period of December 2016 to March 2017, 74 scheduled gate tests at 23 sites were carried out. Six gate systems failed to operate on demand during testing. In 13 other cases, gates operated on demand; however certain equipment malfunctioned or was found to be in unacceptable condition.

Operational restrictions are in place on eight out of 109 flood discharge gates due to known deficiencies (increased from six from the previous quarter). Eleven flood discharge gates are locked out for operational reasons due to winter conditions (changed from six from the last quarter). Ruskin has commissioned four out of five new gates and all original gates have been decomissioned.

A total of 45 corrective maintenance issues were identified through ongoing testing and maintenance from December 2016 to March 2017. A total of 49 new and previous issues were addressed in the

same period, for a reduction of four issues overall in this reporting period. There are now 69 corrective maintenance issues outstanding at the end of March 2017, which is the same as of one year ago.

CIVIL MAINTENANCE

Management of the dam safety related civil maintenance projects was moved from Dam Safety to Generation Maintenance in Q4. Twenty-seven projects were completed in Fiscal 2017. These include penstock inspections and support repairs, La Joie Dam upstream dam face shotcreting and intake inspections, various concrete and joint repairs, vegetation removal, spillway concrete inspections and repairs, tunnel inspections, a rock trap cleanout and underwater surveys, road repairs and head pond dredging at Wilsey Dam. Three additional projects were completed in F2017 as X-plan. The F2018 plan has been finalized, with 47 projects and a budget of $5.2 Million. Projects will commence in April 2017.

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 preliminary design report for the decommissioning of Salmon River Diversion Dam was submitted in Q4.

BC Hydro's interpretation and application of the revised Dam Safety Regulation was finalized in the Dam Safety Governance Manual and submitted to the Comptroller of Water Rights in Q4. Concurrance of our approach was received by letter in late Q4.

Inspections

A total of 365 out of 375 (97.3%) inspections were completed during Q4. Inspections were not missed on two consecutive weeks at any facility. The missed inspections were mainly the result of either poor access / road conditions due to snow and ice or a lack of available staff: in the Fraser Valley / Bridge area six weekly inspections were missed out of a total of 96; one monthly inspection was missed at Clayton Falls; and three inspections were missed at Mica during Q4. At Mica, the Upper Columbia Generation took over responsibility for completing the inspections from a contractor in Q3. Since that transition, a total of five inspections have been missed. Dam Safety has followed up with the site to emphasise the importance of completing the regulatory inspections as scheduled.

Discussion/Information

As previously noted, road access into Bear Creek Dam is not possible due to rotten wooden bridges and an uncleared landslide. The site is being accessed by helicopter until further notice. All three required inspections of Bear Creek Dam were completed this quarter after missing two of three inspections last quarter.

Dam Safety Reviews

Dam Safety Reviews are a regulatory requirement carried out at minimum intervals of every five to 10 years at high, very high and extreme consequence dams. Four Dam Safety Reviews are currently in progress: Cheakamus, Comox, John Hart and Stave Falls. Draft reports were received for Cheakamus and Comox in Q4. There are five Dam Safety Reviews scheduled for F2018: Alouette, Clayton Falls, Duncan, Seven Mile and Revelstoke. A Request for Proposals for the F2018 work has been posted to BC Bids and will close in Q1.

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 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 VI has been set at the time of the development of the first 10 year capital plan.

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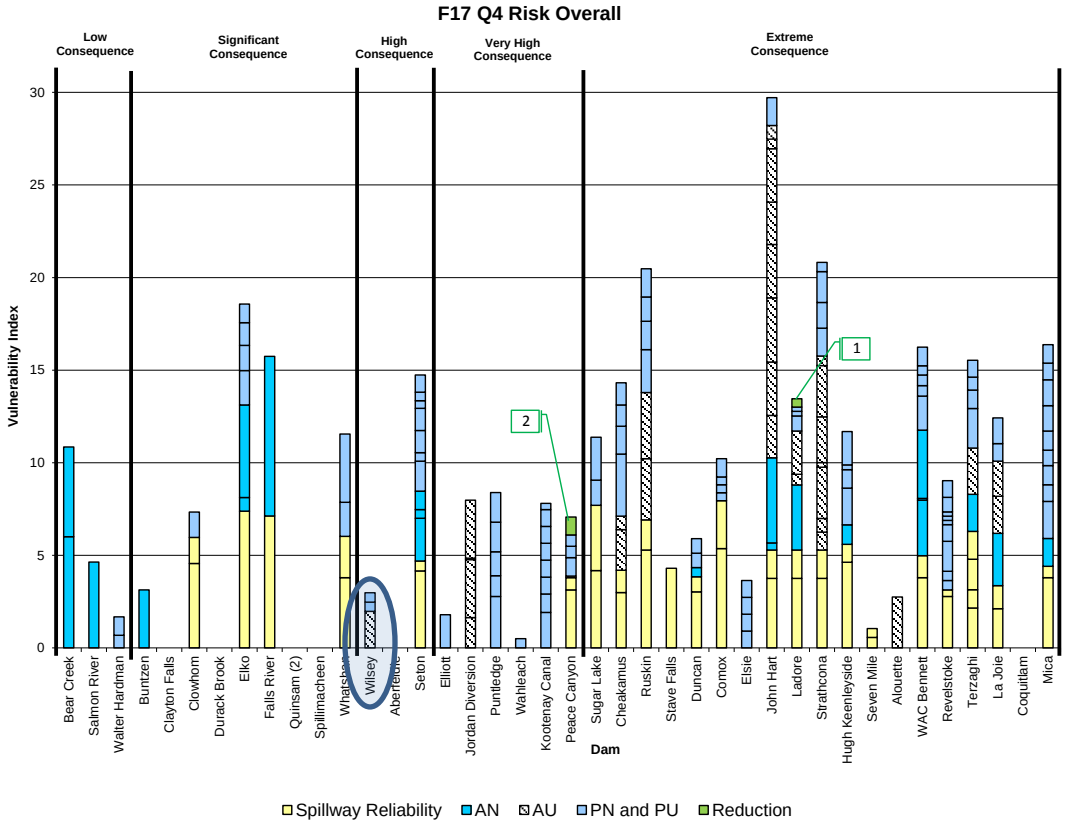
Figure 1 - Dam Safety: Overall Risk Profile



Legend and Summary of Change

Increase in Risk — ***None this quarter***

Reduction Risk

1. ***Ladore Dam –*** *The database was updated to reflect the previously completed stability assessement for seismic loading which determined the dam to be stable for the Maximum Design Earthquake.*
2. ***Peace Canyon Dam –*** *The stability of the dam is sensitive to uplift pressures in the foundation. A model has been developed to allow for rapid assessments of dam stability for changing uplift pressures. The model can be used to determine the requirement for foundation drain maintenance or rehabilitation.*

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.
- 34 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

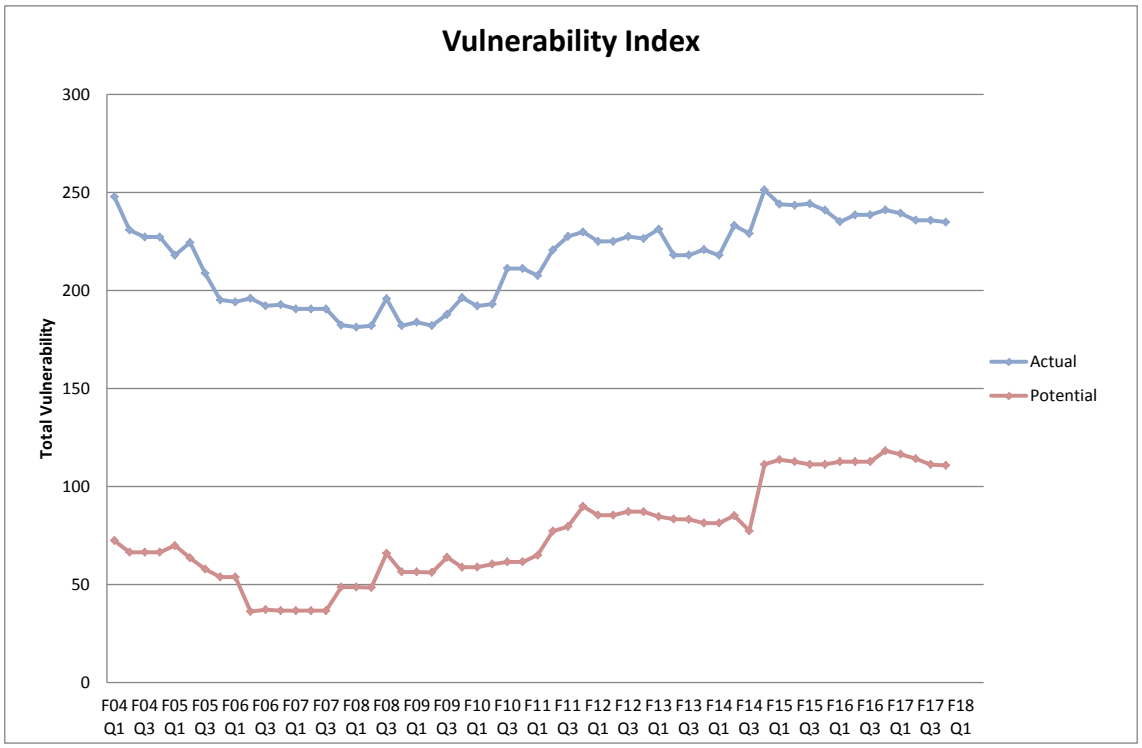


Figure 3 – Change in Total Vulnerability Index Components