2016–2017 Dam Safety Program Report

2016 spillway repairs at WAC Bennett Dam

BC Hydro
Power smart

BCH17–611

Dam Safety Program Report April 2016 – March 2017 (F2017)

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Overview

BC Hydro currently owns, operates and maintains 80 dams at 41 sites across British Columbia. As owner of these dams, BC Hydro manages risks to public and employee safety, the environment, reliability of electricity supply and the financial well being of the company. To manage these risks, BC Hydro has a comprehensive dam safety program, which has been compared favorably to the leading programs around the world. Within this program, issues with the dams are identified and assessed. Plans are in place to address the issues in priority sequence and prior to completion, risks are managed through interim measures. The Deputy Chief Executive Officer provides oversight to the management of the wide range of risks associated with these dams. The BC Hydro Board of Directors receives quarterly reports on the Dam Safety program, and the Provincial Government receives annual reports, including a summary of new issues identified, assessment of risk, and progress on implementation plans.

BC Hydro continues to provide leadership at national and international levels in the development of a risk-informed approach to dam safety management, and in bringing dam safety practices into line with those of other hazardous installations that create a wide range of societal risks. Such an approach is required to address the problem of escalating expectations for protection against extreme floods and earthquakes, by providing a balanced approach to decision-making that considers all risks to people, property and the environment.

To meet the requirements of the Dam Safety Regulation, BC Hydro's dam safety program is based on inspections, independent expert reviews, and monitoring of instrumentation data from the dams. Potential deficiencies are identified for further study, and when dam safety improvements are found to be necessary, the projects are prioritized and brought into BC Hydro's capital planning process. This report provides a summary of activities and events for the past fiscal year ending March 31, 2017.

Contents

Introduction

BC Hydro's dams

BC Hydro currently owns, operates and maintains 80 dams at 41 dam sites in British Columbia, as a major part of its generating system. The dam sites are listed in Appendix A. The dams are classified as per the Dam Safety Regulation (B.C. Reg. 40/2016, February 29, 2016).

Owner's responsibilities

BC Hydro is accountable to the Government of British Columbia and to the Comptroller of Water Rights, for ensuring the safety of BC Hydro dams in accordance with the Dam Safety Regulation.

As a dam owner, BC Hydro manages risks to public and employee safety, the environment, reliability of electricity supply and the financial well being of the company. To manage these risks, BC Hydro has a comprehensive dam safety program, which has been compared favorably to the leading programs around the world.

BC Hydro's commitment to dam safety is outlined in the Dam Safety Governance Manual, which includes a Statement on BC Hydro's Approach to Managing Risks from Dams (see next section) that has been approved by the Board of Directors.

Dam Safety Statement

Dam Safety Statement

Large dams involve risk, risk which is accepted for the benefits that accrue from relatively inexpensive and environmentally sustainable electricity and from flood control.

Our dams have been, and are, built on the basis of good practice existing at the time of their construction and a proven approach ensuring that they are as strong and as safe as it is practicable to make them.

Though ageing and normal wear and tear present constant challenges, and new threats sometimes emerge, our aim is to manage the whole fleet of dams, so that there is no significant deterioration in the risk position and that the overall level of risk is kept well within limits considered to be tolerable. To exclude risk altogether is impossible, for this or for any significant hazard.

Our method is to keep the condition of the dams and the risks they present under constant review within the requirements of the BC Dam Safety Regulations, and to identify and measure, so far as possible, any new threats, and to make any necessary improvements and repairs as soon as it is practicable.

Our approach takes account of engineering analyses, potential consequences and cost. Whenever it is possible to make improvements or necessary to take remedial measures, we first refer to international and Canadian best practices, seeking to achieve as large an increment to safety as possible, and at the very minimum, not to accept any reduction in the level of safety. We therefore seek to balance the cost of each possible improvement against the added safety it would achieve, erring always on the side of safety, and subject to the over-riding condition that if the resulting risk level is less than acceptable, the reservoir elevation would be reduced to restore the level of safety or the dam would be taken out of service.

The whole approach involves constant monitoring and estimation of risks and threats, taking advantage of lessons learned worldwide. It implies an ongoing program of review, with improvements, and remedial actions where necessary prioritised according to

(a) the size and significance of the added safety that can be achieved, in relation to the cost
(b) the degree of urgency

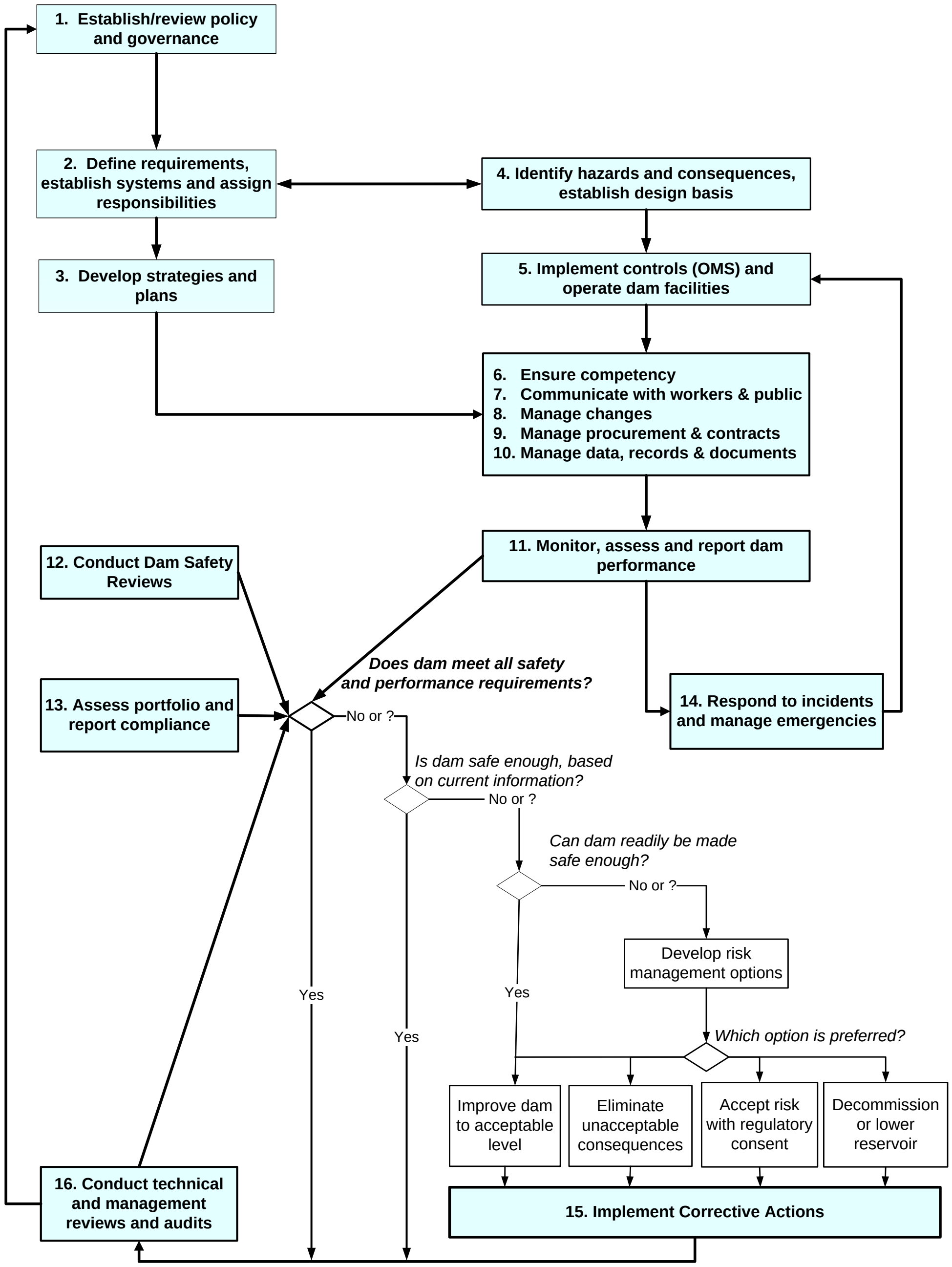
while recognizing the need to ensure the application of the best possible expertise.

BC Hydro's Dam Safety Management System

The objective of the dam safety program is to manage the safety of physical features and structures that retain the reservoirs and control passage of flows through, around and beyond dams that are operated by BC Hydro, thus protecting both the public and the corporation.

BC Hydro develops and maintains world-class capability in risk assessment and dam safety engineering, and is committed to providing the resources to meet or exceed dam safety guidelines and expectations that are acceptable to BC Hydro's Board of Directors and the Government of British Columbia. BC Hydro representatives communicate regularly with the Comptroller of Water Rights, who represents the Government of British Columbia in relation to dam safety matters.

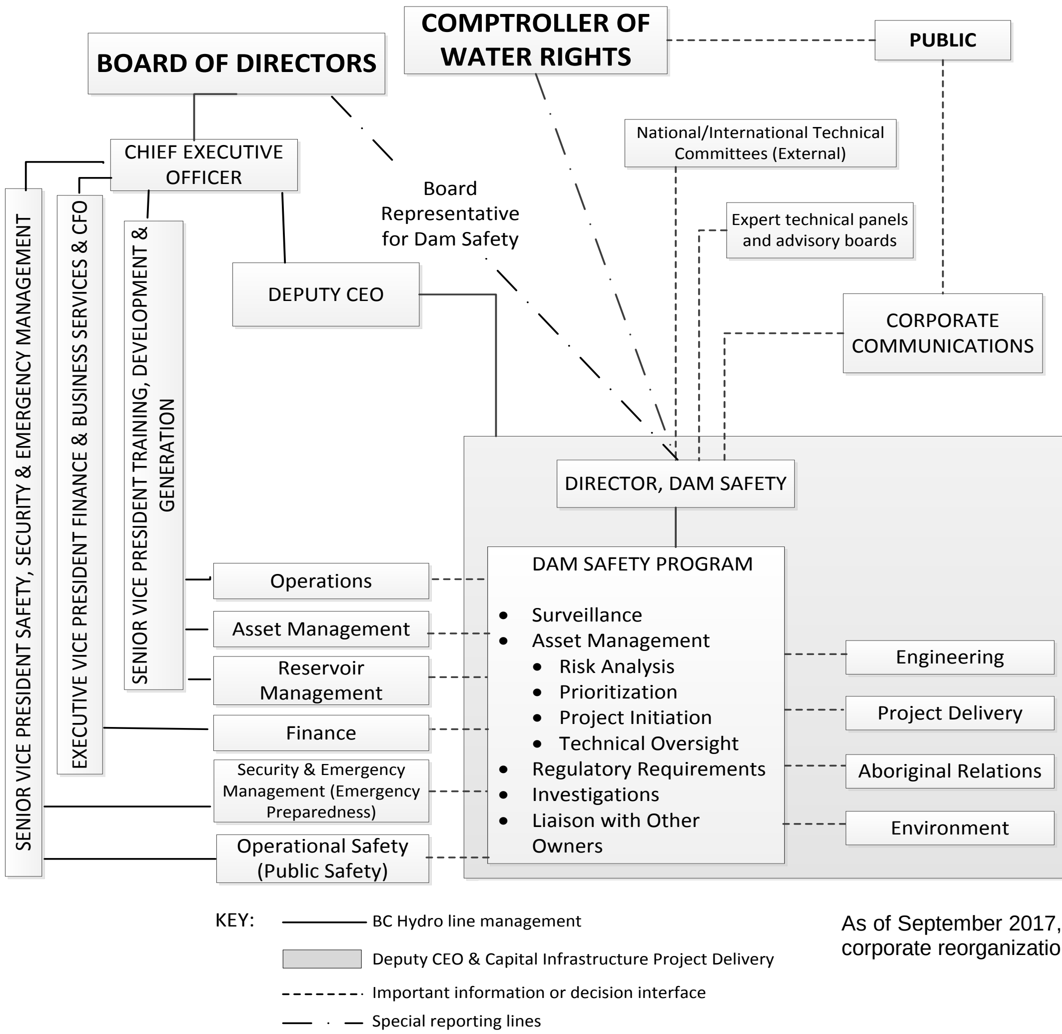
The key elements of the Dam Safety Management System are illustrated in the figure below.



Governance and Organization

Governance

Governance and implementation of dam safety at BC Hydro is shown on the chart below. Mr. John Ritchie has the role as the Board representative for dam safety. The responsibility for dam safety is shared between the Deputy Chief Executive Officer, Mr. Chris O'Riley and the Director of Dam Safety, Mr. Stephen Rigbey. The Director meets quarterly with the Board representative.



As of September 2017, prior to corporate reorganization

Dam Safety Program

The Dam Safety Program is implemented by the Dam Safety department with a staff of thirty-five. This includes seven dam safety area engineers supported by nine instrumentation technologists, most of who are resident in the generating regions and are involved in all dam safety activities at the dams. Coordination and support related to instrumentation systems, regulatory requirements, risk management, and the program of dam safety investigations and capital upgrades, is provided by staff at Edmonds who report directly to the Director of Dam Safety.

The Deputy Chief Executive Officer provides corporate oversight of the dam safety program.

Advisory Boards and Technical Panels

The Director of Dam Safety convenes Advisory Boards and Technical Panels to provide independent interpretation of the engineering and scientific information used to inform decision-making, or to provide guidance on decision-making concerning complex or unique matters of societal risk. Up to three or four independent subject-matter experts of international repute, with complementary expertise suited to the type of issue under consideration, make up the Boards. A similar composition of subject matter experts form Technical Panels; however such panels are requested to work at a more detailed engineering level.

The John Hart Advisory Board Meeting #2 was held in July 2016. The Board consists of 4 members, 3 from the US and 1 from New Zealand. Their expertise includes seismic performance assessments, design and construction expertise for earthfill and concrete dams and design of gates, particularly in seismic areas. At Meeting #2, the team presented conceptual upgrade options for the Middle, North, Intake and Concrete Dams, including addressing the recommendations from the Board from Meeting #1. The Board endorsed the concept of an upstream stabilizing berm combined with a downstream plastic concrete cut-off wall at the Middle Earthfill Dam, a buttress and/or an excavate replace option for the North Earthfill Dam, and a buttress option for the Intake Dam. The Board recommended the team review the need for an additional plastic concrete cut-off wall at the Intake Dam. The Board also recommended to consider options that include pier and gate replacement as well as to review the reliance on the existing post-tensioned anchors for the cross-valley direction stability, and for the team to review the options for the Concrete Dam and the gates. The Board endorsed the recommendation to construct an overflow spillway at the non-overflow sections of the Concrete Dam to address the flow imbalance concrete at John Hart Dam.

The 11th Ruskin Dam Advisory Board meeting was convened in November/December 2016 to provide advice on the ongoing construction of the upper part of the dam and on the seismic re-analyses of the dam. The team presented the results of the re-analyses of the dam, and the Board endorsed the team's findings. The Board also made recommendations regarding the seepage testing at the right abutment cut-off wall and reiterated the need for the team to determine if additional anchors would be required for the Intake structure at the left abutment.

Dam Risk Management

Management System

The dam safety management system is described in detail in the Dam Safety Governance Manual. Application of the Dam Safety Governance Manual is documented in the Dam Safety Program Implementation Manual.

Dam risks are generally identified through surveillance activities or the periodic independent expert dam safety reviews for each dam. Once a potential or actual deficiency is identified, it is entered in the dam safety database, and then tracked through to resolution. A key aspect of the risk management process is prioritization of the deficiencies.

Dam Risk Matrix

The BC Hydro dam prioritization system develops a "Vulnerability Index" (VI) rating for each dam which is a surrogate for probability of future poor dam performance. This is an aggregate rating based on all known issues or departures from good practice or current standards.

The VI is the sum of known individual rated deficiencies. The deficiencies are defined as Actual (shown to exist) or Potential (require further investigation) and can occur under either Normal (associated with daily or short-term operations) or Unusual (associated with flood and earthquake) loading conditions. The deficiencies are rated on the basis of a number of different variables, including: the extent to which the design of the deficient feature varies from accepted good practice, the extent to which the deficient feature compromises the safe performance of the dam, the frequency at which the deficient feature is tested and the effectiveness of any interim risk controls in place.

The VI rating is plotted against the estimated consequences of failure to represent a measure or index of risk. The Risk Matrix (Figure 1) represents the fiscal year-end status for all the dams with identified actual deficiencies and potential deficiencies for the past two years. The dams are shown in groups as per their consequence category based on the BC Dam Safety Regulation.

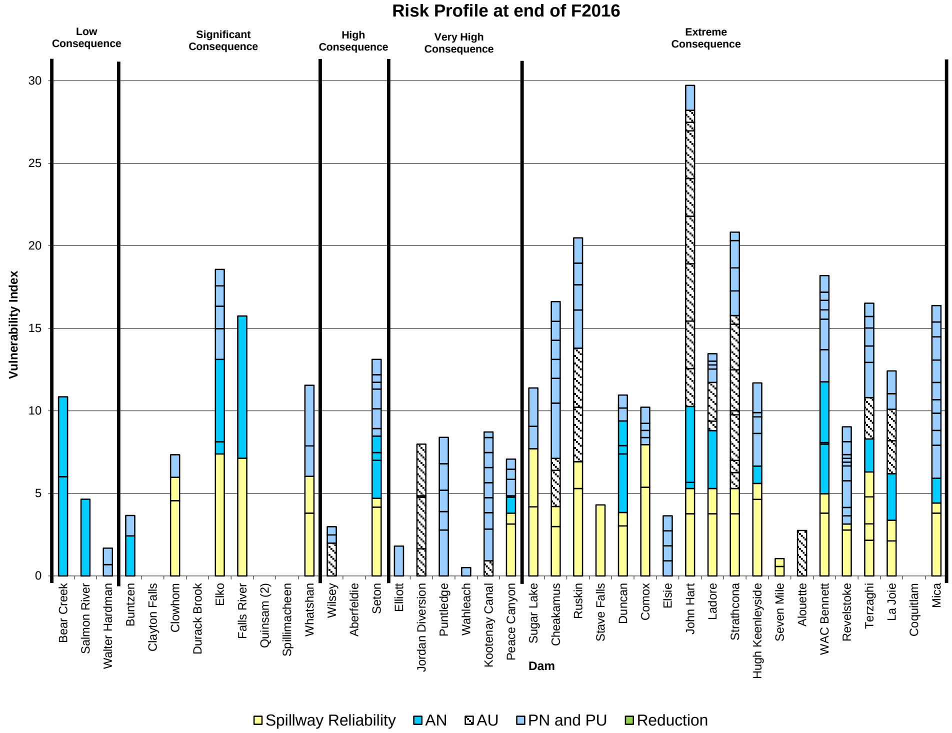
The term "risk" is used here in a general sense; it is not a direct measure of the probability of failure multiplied by the consequences. Although desirable, dam risks cannot yet be reliably quantified.

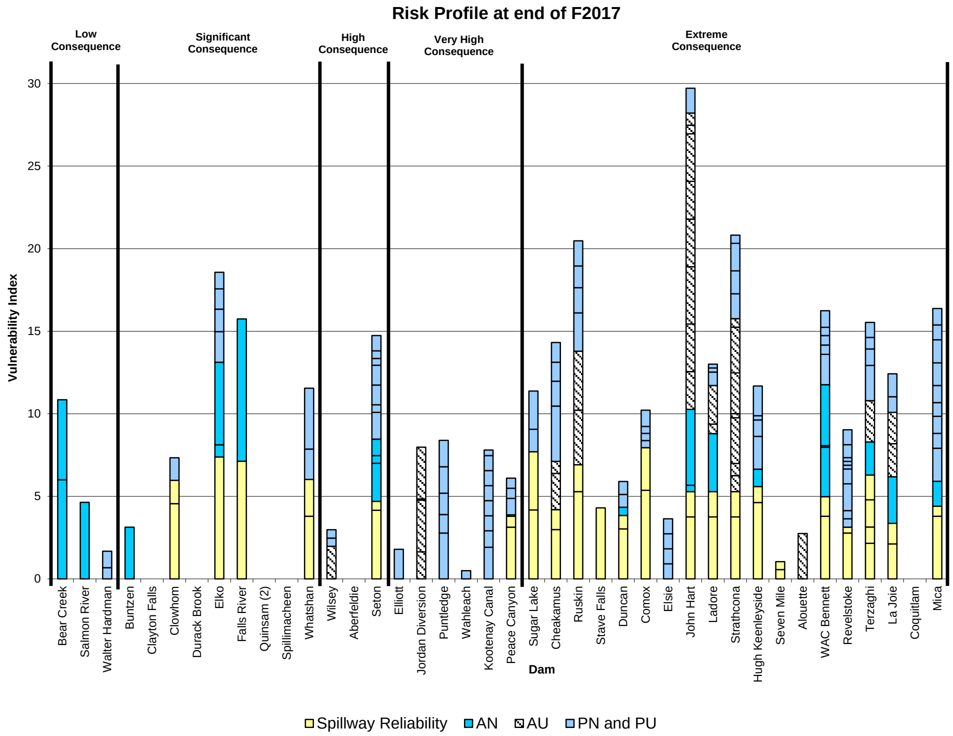
Risk Profile

The risk profile shown in Figure 2 plots the VI total on a quarterly basis. An increase in the VI is a measure of increasing known information and potential issues about the dams, which will guide future investigation and capital planning. As new deficiencies are identified, and as existing deficiencies are addressed, the risk profile is adjusted and reported quarterly.

Priority attention is paid to dams in the Very High and Extreme consequence classification and to deficiencies classified as "Actual Normal". The management goal is to move the VI position downwards for each dam. In general, dams will reach a background risk that cannot be easily reduced further. This background risk is not represented in Figures 1 or 2.

FIGURE 1: RISK MATRIX



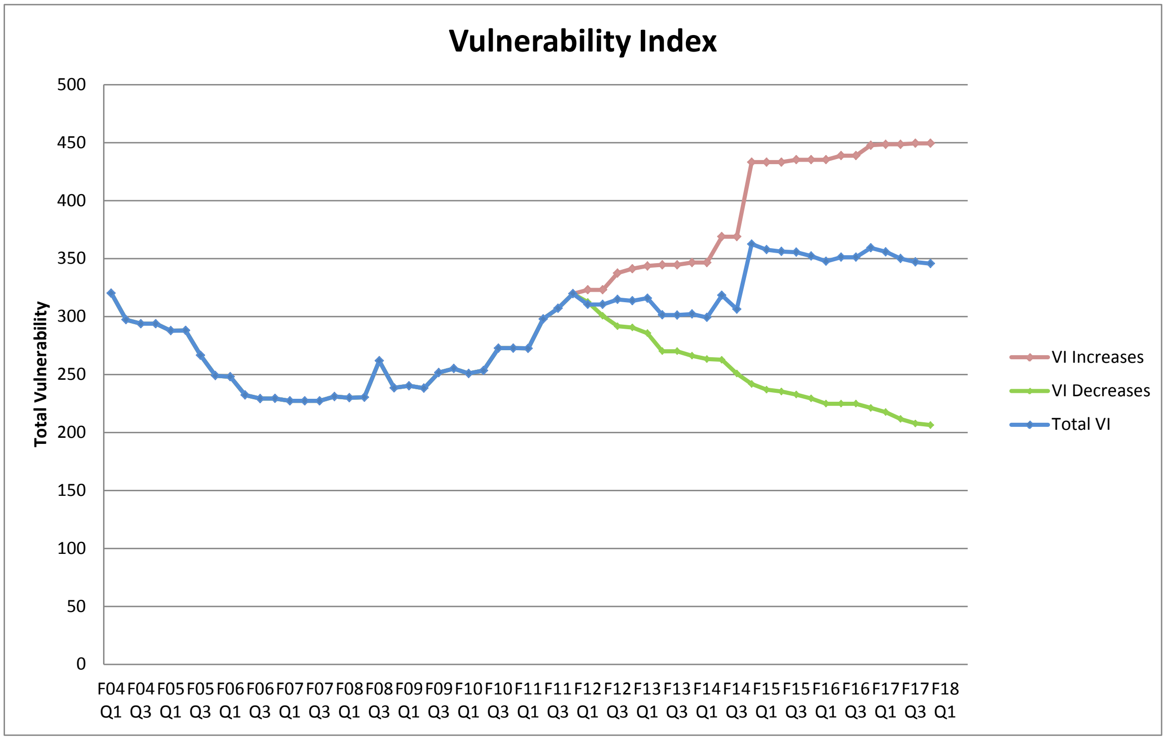


Legend:

Actual	Actual deficiencies have been shown to exist.
Potential	Potential deficiencies require further investigation.
Normal	Normal Load conditions; associated with daily or short-term operations.
Unusual	Unusual Load conditions : associated with flood and earthquakes
Spillway Reliability	Actual Normal deficiencies associated with the reliability of the spillway gates

How to Interpret Risk Matrix:
The vertical axis, the 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. The horizontal axis shows the dam in increasing order of consequence as classified in the BC Hydro Dam Safety Governance Manual.

FIGURE 2: RISK PROFILE



There has been an overall decrease in the VI this past year due to decreases at Duncan, WAC Bennett and Terzaghi Dams, as well as smaller decreases at Buntzen, Kootenay Canal, Peace Canyon, Cheakamus, and Ladore Dams, (see Figure 1). There have been small increases at Buntzen and Terzaghi Dams.

Completion of the cut-off wall in Duncan Dam, completion of the WAC Bennett spillway chute upgrades and a reassessment of the seismic deficiencies at Terzaghi Dam resulted in the largest decreases in VI. Other work that resulted in decreases were: confirmation that the previously completed canal lining at Kootenay Canal is effective; downgrading of concern over the condition of the spillway at Buntzen; refurbishment of the toe drain system at Duncan Dam; a reassessment of seismic deficiencies at Cheakamus Dam; completion of a stability model for Peace Canyon Dam and completion of the Ladore Dam stability assessment under seismic loading.

The small increases in VI are related to the small capacity of the Buntzen spillway and the post-seismic operability of the low level outlet gates at Terzaghi Dam.

Risk Reduction Projects The major dam safety initiated risk reduction projects that are estimated to exceed $2 million and were in progress or completed at the end of March, 2017 (end Fiscal 2017) are listed in the table below. Descriptions of the work undertaken are given in the Project Activities section of this report.

Dam	*Major Upgrade Items*	*Status*
Alouette	Intake Structures Seismic Upgrade	In-progress
Bridge River 1	Penstock Leak Detection & Protection	In-progress
Bridge River 1	Slope Drainage Improvements	In-progress
Bugaboo Diversion	Decommissioning	In-progress
Clowhom Dam	Gate Control Improvements	In-progress
Comox – Puntledge	Flow Control Improvements	In-progress
John Hart	Seismic Upgrade	In-progress
Jordan River	Mitigate Seismic Risk	In Progress
Ladore Dam	Spillway Seismic Upgrade	In-progress
Peace Canyon	Gate Reliability Upgrades	In-progress
Revelstoke	Marble Shear Block	In Progress
Ruskin	Seismic Upgrade	In-progress
Salmon River	Decommissioning	In-progress
Strathcona	Discharge Upgrades	In-progress
Sugar Lake	Gate Reliability Upgrades	In-progress
W.A.C. Bennett	Gate Reliability Upgrades	In-progress
W.A.C. Bennett	Rip Rap	In-progress
W.A.C. Bennett	Core Casings Upgrade	In-progress
Wahleach	Tailrace Upgrade	In Progress
Wahleach	Instrumentation	In Progress
Wahleach	Over velocity Detection Device	In Progress
Walter Hardman	Instrumentation	In Progress
Various Sites	Rock Correction of Seismic Ground Motions	In-progress
Various Sites	Debris Booms	In-progress
Duncan Dam	Install Core Cut-off Wall	Completed
Duncan Dam	Instrumentation Improvements	Completed
Hugh Keenleyside	Gate Reliability Upgrades	Completed
W.A.C. Bennett	Spillway Chute	Completed

Performance Investigations

Performance Investigations are initiated for potential deficiencies in priority order. Potential deficiencies are defined in the Dam Safety Governance Manual as *Concerns pertaining to adequacy in performance that are expected to be confirmed as "Actual Deficiencies" or where analysis reveals that the uncertainties are such that dam safety improvements are necessary, or where the concerns, if not demonstrated as not being concerns, would result in dam safety improvements.* These potential deficiencies include those where work was underway in Fiscal 2017 as listed below. Descriptions of the work undertaken are given in the Project Activities section of this report.

	Dam	*Issue/Investigation*
Investigations Underway		
	Cheakamus	Barrier Slide Failure Risk Assessment
	Coquitlam	Data Compilation
	Hugh Keenleyside	Low Level Outlet Operations
	La Joie	Seismic Performance of Water Passage System
	Mica	Spillway Seismic Performance Assessment
	Special Investigations, Embankment Dams (WAC Bennett-Mica)	Performance Assessment
	Strathcona	Seismic Performance Assessment
Completed Investigations Fiscal 2017		
	Ladore	Seismic Stability
	Peace Canyon	Seismic Stability
	Terzaghi	Seismic Performance of Embankment Dam (the main seismic performance investigation works completed in F2016-Data compilation work continued and completed in F2017)

Initiatives

Dam Safety undertakes initiatives in order to further improve the state of knowledge of risks related to dam safety to ensure that engineering solutions are appropriate and capital money is spent wisely. The following initiatives were underway this past fiscal year. Descriptions of the work undertaken are given in the Project Activities section of this report.

	Dam	*Possible Issues*
Initiatives Underway		
	System-wide	Dam Safety Information System development
	System-wide	Stochastic Modeling of Extreme Floods – Columbia River System
	System wide	Tolerability of Risk – development of a decision framework
	System wide	Remote Sensing for Landslide Detection
Completed Initiatives in Fiscal 2017		
	System-wide	Water License Dams – review of corporate responsibilities at small dams where ownership/licenses may be shared with other entities
	System wide	Reservoir Level Monitoring and Gates Heating

Regulatory Activities

The key requirements of the BC Dam Safety Regulation include the following activities.

Site Surveillance

A total of 1581 or 98.1% of planned inspections were completed in F2017. Nineteen scheduled inspections were missed due to weather-related access difficulties or unavailable personnel. There have been no two successive missed inspections at any site.

Formal Dam Inspections

Annual or semi-annual surveillance inspections and reports were completed for all dams for F2017 as per regulatory requirements.

Instrumentation and Surveys

Dam instruments were read and recorded, and surveys completed throughout the year in accordance with the schedule submitted to the Regulator.

Gate Testing

Since August 2006, the flood discharge gates have been regularly tested, with gates at higher criticality sites tested monthly. In general, spillway gates at Significant and Low Consequence facilities are tested quarterly. The tests have helped verify availability, detect equipment and operational problems, and provide regular training to plant staff in spillway gate operation.

More than 200 inspections and tests were undertaken in F2017, covering all spillway gates in the BC Hydro system. Regular gate testing is a key element in sustaining staff familiarity to the equipment and to timely detect and restore the failed components.

Emergency Plans

All emergency plans and planning guides were reviewed in F2017. Some revisions have been delayed into Q2 F2018 as a major update to the emergency plans is in progress.

Efforts are ongoing to work with communities on preparing flood inundation maps for public education. In 2017 a community flood map for the Squamish Valley downstream of Daisy Lake (Cheakamus) Dam was jointly produced by the Squamish District, Squamish Lillooet Regional District, Squamish First Nations and BC Hydro. It is available electronically and being distributed in hard copy at community events and emergency response exercises. The Comox Valley Emergency Program expressed renewed interest in having flood maps prepared for the inundation area below Comox and Puntledge Dams. BC Hydro will continue to work with response agencies and local municipalities to improve emergency plans, public education and inundation maps.

Operation, Maintenance and Surveillance (OMS) Manuals

There is an ongoing program to update OMS Manuals. In F2017, four of the eleven planned updates to OMS Manuals were completed and another four are nearing completion.

Dam Safety Reviews

These periodic detailed reviews of dam performance and assessment against current guidelines are required on a five to ten year schedule for dams where the consequences of failure are High, Very High or Extreme and on a ten to fifteen year schedule for dams where the consequences of failure are Significant or Low.

In F2017, Dam Safety Reviews were initiated for Cheakamus, Comox, John Hart and Stave Falls Dams and draft reports submitted. The final reports are expected in early F2018. A Request for Proposals for the F2018 Dam Safety Reviews was posted to BC Bids for Alouette, Clayton Falls, Duncan, Revelstoke and Seven Mile Dams in late F2017.

Once the final reports have been received, the findings will be incorporated into the dam safety management system, and the reports submitted to the Comptroller of Water Rights.

Meetings with Dam Safety Regulator

The Director of Dam Safety met with the Comptroller of Water Rights, together with key staff, on January 20, 2017 to discuss matters of mutual interest. The Manager of Emergency Management met with Dam Safety staff on March 13, 2017 to discuss emergency plans and their provision to them.

F2017 Surveillance

F2017 Update

Surveillance staffs are located throughout the province and are a mix of Professional Engineers, Technologists and admin staff that work closely with Plant staff, as well as Project teams, to address issues which impact dam safety. Surveillance staff monitors and maintain thousands of instruments; collect and assess millions of data points and are on the frontlines for troubleshooting Dam Safety Issues as well as Emergency Response. Surveillance is also responsible for an On Call program that fields Dam Safety related calls 24/7. Among the surveillance topics addressed during F2017 are the following.

- *Ground Based Interferometric Synthetic Aperture Radar (GBInSAR)*

Dam Safety is evaluating Ground Based Interferometric Synthetic Aperture Radar as a Surveillance monitoring tool to detect movement at Checkerboard Creek in Revelstoke. One of the main advantages of radar is that it can "see" through rain and fog.

- *Change in Surveillance Delivery Model*

The Upper Columbia will be the first region to employ a new model for delivering Surveillance. The new model will combine regions under a senior knowledgeable Dam Safety Engineer with technical oversight over a regional Surveillance Engineer(s). In this case the Dam Safety Engineer will have oversight for the Upper Columbia and Reservoir Slopes with an Upper Columbia Surveillance Engineer and a Reservoir Slopes Geologist. This model provides for mentoring, succession planning, technical oversight and knowledge transfer.

- *Lower Columbia Emergency Planning with United States counterparts at Libby Dam*

The Lower Columbia Dam Safety Engineer was invited to an Emergency Planning session at Libby Dam in the United States. The discussion was to help develop a scenario and coordinate a joint emergency exercise.

- *Norwegian Geotechnical Institute (NGI) invited Surveillance Reservoir Slopes Specialist to Norway to discuss landslide stabilization*

The Surveillance Reservoir Slopes Specialist was invited to Norway to discuss landslide stabilization and what BC Hydro has accomplished. This was followed up by a Norwegian delegation visiting Downie Slide and Dutchman's Ridge to examine the stabilization works. The exchange of information was fruitful for both parties as each had different strengths and experiences. BC Hydro had more experience in direct drainage of landslide slopes and the Norwegian Geotechnical Institute had more experience with LiDAR and InSAR.

- *Aerial work*

Aerial drone work was carried out at La Joie, Seven Mile, Coquitlam, Buntzen, Terzaghi and Downie Slide. The drone is capable of high resolution photos and creating three dimensional models of dams and spillways that does not require lockout for man access, which is a major benefit. The information gathered can be used for measuring defects and planning repair work.

Project Activities at BC Hydro Dams

The safety status of BC Hydro dams is assessed through ongoing surveillance, periodic Dam Safety Reviews and investigations. When necessary, capital improvement projects are then planned and carried out. The major projects are summarized below.

Projects Completed in Fiscal 2017 – Capital Improvements


Sheet pile wall layout


Restoration of the upstream rip rap


Hugh Keenleyside gates

- ***Duncan Dam – Installation of Core Cutoff Wall***

During a 2015 field investigation, the top of the core was confirmed to be lower than expected for a length of approximately 500 feet from the left abutment. As a result, the core does not provide enough freeboard for BC Hydro to surcharge Duncan Reservoir in the event of high inflows when the reservoir is full. As an interim measure, the Operation, Maintenance and Surveillance Manual was modified to prohibit surcharging of the reservoir.

A project was initiated in January 2016 to address this issue on an urgent basis, with a target for completion prior to freshet 2016 (i.e. July). A decision was made in early January to install a new sheet-pile cutoff wall from the top of the dam intersecting the existing dam core over the 500 foot of length from the left abutment. The field work was carried out from May to June, and the project documentation was completed by July. The top of the sheet-pile has now been constructed to the same elevation as the original designed top of the core, consistent with the remainder of the dam. With the successful completion of the construction, the restriction on surcharging the Duncan Reservoir was successfully removed prior to the 2016 freshet.

- ***Hugh Keenleyside Dam – Spillway Gate Reliability***

The Hugh Keenleyside Dam Gate Project, initiated to improve the power supply and distribution, gate controls, strengthen the tower at the spillway, and replace drives and hoist at the spillway and the low level outlets, has been put in service in F2017. There are a number of outstanding deficiencies currently being rectified. Once these are completed, the resultant reduction in Vulnerability Index will be reported.

Resurfacing of lower portion of spillway chute, July 2016

WAC Bennett Dam Spillway Chute – completed, September 2016

- ***W.A.C. Bennett – Spillway Chute***

This project carried out repairs to the spillway chute concrete surface at the W.A.C. Bennett Dam. Safe access to the chute was achieved in August 2011 following completion of rock slope stabilization works which allowed for a complete chute inspection.

This project was initiated in F2012. In F2013, high priority work was completed, including the following works:

- installation of waterstops in the upstream construction and contraction joints,
- repairs of significant cracks by removal of the cracked concrete and replacement with new concrete, and
- minor patching of other cracks.

The contract to carry out the resurfacing work on the inclined portion of the spillway was awarded in late F2014, and the construction was planned over two construction seasons. The first year of construction was started in spring/summer 2014. The surface concrete was removed by hydro-demolition. Additional dowels / anchors / rebar were installed, and new concrete was placed meeting the tight tolerance requirements. About three quarters of the planned concrete removal / resurfacing work was completed in year 1. Due to the high risk of spill, however, a decision was made in late F2015 not to proceed with construction in 2015. The second year of construction was started 2016, where the remainder of the resurfacing of the upper portion and the entire lower portion of the chute was completed by the end of September. In addition, the 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.

Active Projects – Capital Improvements

System-wide Projects

Peace Canyon

➢ ***Gate Reliability Program***

The Gate Reliability Improvement Program capital work began in F2006. It represents a major step towards improving BC Hydro's spillway gate systems, and supporting BC Hydro's longer term goal of meeting international best practice in gate reliability. Implementation at BC Hydro gated sites is scheduled for improvement on a prioritized sequence.

Ten sites were identified as requiring first tier priority work. The gate systems at 9 out of the 10 sites have been put in service in previous years. During F2017, construction continued at the remaining site, Ruskin.

The second tier projects will be limited to selected upgrades of the electrical and mechanical equipment for cost-effective early risk reductions. The first two projects in the second tier priority sites, WAC Bennett and Peace Canyon, are currently in Definition phase. Conceptual design for Clowhom Dam gate control system has commenced. Sugar Lake Dam gate improvement has been deferred to allow better understanding of the various water conveyance requirements (dam safety and regulatory) at the facility. These projects are discussed in the Site Specific Projects section below.

Boom at Hugh Keenleyside

➢ ***Reservoir Boom Replacement***

BC Hydro has 49 debris booms in our reservoirs. Many are aged, in poor condition. In 2015, a replacement strategy was developed:

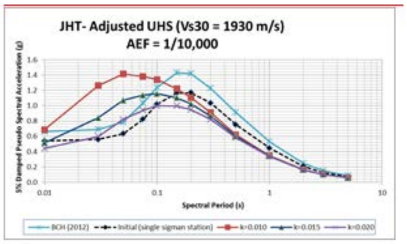
(i) On sites where there is a pressing need for repairs or replacement, proceed with like-for-like replacements.

(ii) On sites where there is more time, review the existing boom designs for opportunities to achieve improvements. This includes an assessment of alternate materials, upgraded log designs, incorporation of public safety requirements, and any other approaches that may be out there.

For (i), the debris boom at Hugh Keenleyside has been replaced on an essentially like-for-like basis in F2017. The Revelstoke debris boom is under way and will be completed in F2018.

Possible 'next generation boom'

For (ii), pilot projects to explore "next generation boom" design, which will encompass both debris interception and public safety functions, and will comprise steel or plastic pontoons rather than timber sticks, will be initiated at Kootenay Canal and Seven Mile in F2018.



➢ *Rock Correction of Seismic Ground Motions*

The 2012 BC Hydro Probabilistic Seismic Hazard Analysis model was developed to compute the seismic ground motions at a site based on its geographic location and a generic reference rock condition. A need was identified to further enhance the model output by taking dam site-specific rock conditions into account at each dam site. An initial assessment showed that computed ground motions could be significantly underestimated or overestimated if site specific rock conditions are ignored.

This project was started in F2015 with the objective to develop a scientifically sound, stable and defensible methodology for correcting the seismic ground motions computed using the current BC Hydro Probabilistic Seismic Hazard Analysis model. A technical team, consisting of the world-wide experts, was assembled to participate in this project. Strong motion data recorded at seismograph stations near BC Hydro's dam sites were retrieved, compiled and processed. Geological characterization was completed for the dam sites and at the seismograph stations. Currently, the recording data is being assessed by the technical team to analyze for the site specific correction factors.

In F2016, initial results for the site specific rock corrections for the various dam sites in BC were computed. Further review, additional field work, and project documentation is planned for F2018.

Site Specific Projects (in alphabetical order)


Alouette Surge Shaft


Alouette Headworks Tower

- ***Alouette Dam- Headworks and Surge Tower Seismic Upgrade***

Alouette Dam and powerhouse consist of a dam and spillway at the south end of Alouette Lake and a power tunnel located in rock from Alouette Lake to the 9 MW Alouette powerhouse which discharges into Stave Lake. The powerplant was taken out of service in 2010.

Due to the predicted damage to the spillway slabs and walls in a large earthquake, the Alouette spillway cannot be relied upon post-earthquake to pass the inflows into Alouette Lake. Given the technical uncertainty of reliably upgrading the spillway, Dam Safety has elected to upgrade the headworks tower and shaft, the surge tower and shaft, the slopes adjacent to these structures and the mechanical items required to allow operation post-earthquake, such that the reservoir inflows can be safely discharged through the power tunnel and adit tunnel to Stave Lake.

The project was initiated in F2016, with a project objective of an upgrading the power tunnel/adit tunnel such that it can be relied on to pass the Alouette Lake inflows to Stave Lake post maximum design earthquake.

In F2017, the project assessed the condition and design of the various components (the headworks tower and shaft, the slopes upstream and downstream of the headworks tower, the headworks operating gate, the surge tower and shaft, and the slopes upstream of the surge tower). Various conceptual options were identified, and the preferred options were selected. Given that the concrete appears to be in relatively good condition, the preferred options include retrofitting of the headwork and surge towers and shafts, replacement of the headworks operating gate, various slope stabilization measures. Further work is planned in F2018 to carry out feasibility design of these options.

Bridge River I - Penstocks

Flowmeter Layout   PIV4 Cable Tray

➢ ***Bridge River 1 – Penstock Leak Detection & Protection***

Bridge River 1 has a history of geotechnical issues. The powerhouse is situated on soils subject to artesian uplift pressures. Extensive remedial measures were required early in the plant's life to arrest rotational movement between the powerhouse and the Bridge River 1 penstocks. The upper portions of the penstocks are founded on a more stable rock foundation on the side of Mission Mountain above the powerhouse.

This project is installing appropriate instrumentation to monitor for penstock leakage and differential movement between the penstocks and powerhouse; detect elevated powerhouse foundation pore pressures and provide appropriate relief of excess artesian pressures.

Installation and alarming of flowmeters on the penstocks have been completed previously. Detailed design of instrumentation to monitor for movements of the penstocks and powerhouse, as well as design for automatic closure of the penstock inlet valves, were carried out in F2017.

Aerial view of the Bridge powerhouses and penstock slopes

➢ ***Bridge River 1 – Slope Drainage Improvements***

As part of the Bridge River 1 development, a drainage network was constructed to reduce the potential for runoff to elevate artesian pressures and to cause debris flows. This network requires major refurbishment/upgrades.

The project continues to evaluate alternatives for drainage improvements and debris flow mitigation, to reduce the potential impacts to the facilities on the lower slope.


Bugaboo Dam viewed from the left abutment

- ***Bugaboo Diversion – Decommissioning***

Bugaboo Creek Diversion was constructed in 1955 and has been abandoned since the 1957 freshet washed out the spillway control structure. The Comptroller of Water Rights has requested a long term plan for the Diversion. In the absence of a plan, the Water Licence will be cancelled which would leave BC Hydro with ongoing responsibilities for the site, but without legal access. BC Hydro has elected to decommission the dam and power conduit.

This project was started in F2017 and is in the conceptual design stage. The scope of work includes:

- hydrotechnical studies to determine the flows that might be expected through the original channel and evaluate the residual dam height required to prevent flow and erosion through the wetland channel,
- civil/geotechnical studies to determine the methodology for removing the earthfill embankment and spoil areas location,
- aquatic and terrestrial environmental studies to characterize environmental quality, identify areas requiring mitigation and identify required permits and licenses
- archaeology studies to identify any areas of archaeological potential and recommend mitigation, and
- First Nations engagement and consultation.


Clowhom Spillway


Clowhom Spillway- Equipment

- ***Clowhom Dam – Gate Control Improvement***

This is part of the “Tier 2” Gate Program, which is intended to address only the more immediate concerns associated with deteriorated conditions and potential common cause failures associated with selected electrical, mechanical, protection and control equipment. The intention is to provide a comparatively large increase in performance versus cost to achieve an acceptable balance between safety improvements and the investment made, by deferring broader scoped upgrades into the long-term future.

The focus of this project is to replace the almost obsolete mechanical gate control system with a modern digital system. This Project is currently in Identification Phase.


Comox Dam

➢ ***Comox – Puntledge Dams – Flow Control Improvements***

There are identified dam safety and public safety risks associated with the reliability of water conveyance at both Comox and Puntledge. These are primarily associated with the vulnerability of the public in Puntledge River due to spurious flow changes. Two inter-related capital projects were initiated in F2013 - one on river system flow control improvements and another on public safety and river gauge improvements.

The flow control project is assessing vulnerability of flow control along the Comox-Puntledge river system (e.g. spurious opening of Comox spillway gates or spurious closure of Puntledge intake gates) resulting in flow irregularities along the popular and environmentally sensitive public river course parallel to the Puntledge penstock. This project is in Identification Phase.

The complementary public safety project is in Implementation Phase, and will improve water level monitoring to detect flow anomalies and improve public warning infrastructure to mitigate risks in the event of flow anomalies. This project is targeted for completion in F2017.


John Hart Dam


John Hart Dam – Geotechnical Investigation

➢ ***John Hart Dam – Seismic Upgrade***

This project was initiated in F2011 to address the seismic deficiencies associated with the John Hart Dam. The plan is to carry out the construction work after the John Hart Redevelopment Project, which provides a new intake, water passage and powerhouse, has been completed.

Since F2011, the project has assessed various conceptual upgrade options for the Middle and North Earthfill Dams, the Concrete Dam and the existing Intake Dam, as well as conversion of the existing non-overflow sections of the Concrete Dam into an Overflow Spillway.

In F2017, work continued in further developing the upgrade options, which were presented to the John Hart Advisory Board in July. To gain additional stratigraphic information and geotechnical properties, a field investigations program was completed in the area downstream from the Middle Earthfill Dam. This information was used to update the stability analyses and models. For the Middle Earthfill Dam, the preferred option is to construct an upstream berm (into the reservoir) combined with a new plastic concrete cut-off wall downstream of the existing slurry trench wall. Two options were assessed for the North Earthfill Dam, including a similar berm option on both the upstream and downstream slopes or an excavate/replace option. Upgrades planned for the Concrete Dam include a roadway deck upgrade, reinforcing of the upper portions of the dam with anchors, and construction of a free Overflow Spillway. Full replacement of the major spillway gate system components (spillway gate structure, hoist tower structure, hoist system, power supply) is recommended, and designs for this new system were started.

Jordan River Diversion Dam

- ***Jordan River – Mitigate Seismic Risk***

Public disclosure of the seismic withstand issues of the Jordan River dams occurred via individual meetings with the land owners within the Inundation Zone, and a general public meeting was previously held in Sooke in F2015. Liaison with the property owners was initiated at that time, and a property purchase program was started. One property was purchased in F2015, and seven residential parcels of land were purchased in F2016. By the end of F2017, ten out of eleven of the properties have been purchased. Demolition of some of the buildings was completed in F2017, with the remainder to be completed in F2018. Land restoration and rezoning will continue into F2018.

- ***Kootenay Canal – Reservoir Boom Replacement***

See Boom Project above.

Ladore Dam

- ***Ladore Dam – Spillway Seismic Upgrade***

Ladore Dam is a concrete gravity dam located downstream of Strathcona Dam and upstream of John Hart Dam, on the Campbell River System. An assessment has revealed that the spillway gates and hoist structure will be severely damaged in the maximum design earthquake.

This project will design and construct upgrades to the spillway based on the need for reservoir retention to the maximum design earthquake, and post-seismic operability and reliability improvements to ensure flow control. The conceptual design of upgrades was completed in F2017, with a recommendation to replace the existing gates with a new gate/hoist system. Feasibility design will continue in F2018.

Peace Canyon

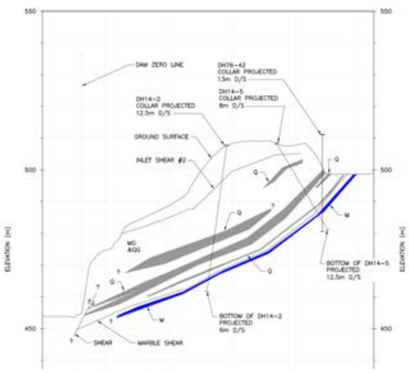
Peace Canyon Spillway Gate

- ***Peace Canyon Dam – Spillway Gate Reliability***

This is part of the “Tier 2” Gate Program, which is intended to address only the more immediate concerns associated with deteriorated conditions and potential common cause failures associated with selected electrical, mechanical, protection and control equipment. The intention is to provide a comparatively large increase in performance versus cost to achieve an acceptable balance between safety improvements and the investment made, by deferring broader scoped upgrades into the long-term future.

This Project is focussed on selected gate components above deck level only, and will include adding defence in depth to the power arrangements and improving remote control of the gates from GM Shrum Control Room. The Project is currently in Definition Phase.

Drilling in the Marble Shear Block



Geological Model Output

➢ ***Revelstoke Dam – Marble Shear Block***

The Marble Shear Block is a large rock mass located on the right bank of the canyon at the Revelstoke Concrete Dam. At the time of construction, some movement of the block occurred during excavation for the dam and powerhouse. Extensive stabilization measures were implemented, and no significant movement has occurred since in the area of the dam and powerhouse. However, downstream of the powerhouse, the Marble Shear is still considered potentially unstable and water levels must be maintained to reduce the likelihood of slope movement.

Significant work was carried out in 1998/99 to reduce water levels but they have since increased. In 2012, a number of drains were cleaned by high pressure jetting and six existing drains were reamed. Ten new drains were also installed at the head of the Marble Shear Block Drainage Adit. The drainage trenches on top of the Marble Shear Block were cleared to reduce ponding. While these measures did impact water levels slightly, the average water level is still above the originally defined acceptable limit.

This project was initiated in F2014, starting with a stability review using updated instrumentation readings and a new numerical model. This work concluded that the stability of the current slope was better than previously analyzed, so long as the Marble Shear Drainage Adit is efficient in draining the toe of the slope. Additional instrumentation was recommended to better evaluate the ongoing performance of the slope.

The installation of five new piezometers was completed in F2015, and the additional geological and piezometric information were obtained.

In F2016, the new information obtained in F2015 was used to update the geological model of the slope and to re-assess the stability of Marble Shear Block. New thresholds have been established for the previously installed instruments to monitor the Marble Shear Block stability into the future.
It was concluded that in order to assist in monitoring these thresholds, two additional in-place inclinometers should be installed within the Marble Shear Block and a detailed LiDAR surveying of the spillway chute should be completed. The work for installation of the new in-place inclinometers was completed in F2017, and the LiDAR survey will be carried out in F2018.

Construction Bulkhead

New Spillway Gates

➢ *Ruskin Dam and Powerhouse – Seismic Upgrades*

The Ruskin Dam Seismic Upgrade includes significant upgrade work to the Right Abutment and Concrete Dam as well as improvements to the Left Abutment intake structure, powerhouse slope and linings of the intake tunnels. This work is being coordinated with the general redevelopment of the powerhouse and switchyard.

The Ruskin reservoir, Hayward Lake, has remained lowered by 1.4 metres since 2007, as a risk mitigation measure at this site.

The dam safety component of the Ruskin Project includes the upgrading of the concrete dam and abutments to address seismic and seepage risks. Previously, work was completed on the right abutment, in the demolition of the old gates 1 to 3, construction of the new piers and new spillway gates 1 and 2. Work was also initiated at the intake structure and the left abutment, with the construction of a reverse filter berm and anchoring of the intake structure.

In F2017, new spillway gates 3 and 4 were successfully constructed and placed in-service, and the temporary bulkhead was again successfully moved and re-attached to the dam for the last phase of construction. Work has also begun on the construction of the final pier and spillway gate. The re-assessment of the Ruskin Dam continued in F2017, moving to the more complex modelling stage. These analyses will determine whether there is a need for additional anchors.

Salmon River Diversion Dam

➢ *Salmon River Diversion – Decommissioning*

This project was initiated in F2014 and first evaluated a broad range of conceptual level options ranging from decommissioning through full redevelopment in order to improve upstream/downstream fish passage and extend the life of the dam and canal. A decision was made at that time to advance the refurbishment alternatives to feasibility design.

In F2015, the selected alternative included an upstream fish passage on the right bank in the footprint of the existing fishway, a new fishscreen and minimal upgrades to the dam and canal. By F2016, work had been completed on the final design of the upstream fish passage, with preparation for construction in spring/summer of 2016. The design of the fish screen and dam/canal upgrades were in progress and the total project costs were updated and re-estimated at $43M. By late F2016, because of the updated cost estimate, a decision was made to cancel construction of the fish ladder and to proceed with the decommissioning solution.

In F2017, the decommissioning option was designed and cost estimated, with summer of 2017 targeted for removal of the dam. An application to cease operations was filed and approved by the British Columbia Utility Commission, and the preliminary design report was submitted to the Comptroller of Water Rights for approval.

Strathcona Dam Spillway

Strathcona Dam

➢ ***Strathcona Dam – Discharge Upgrade***

The construction of a new Low Level Outlet will provide a means to effectively lower the Upper Campbell Reservoir and protect the Strathcona Dam from failure and uncontrolled release of the reservoir in either a static or a post-seismic situation. The seismic withstand of the intake tower is currently 1:800, and its failure could seriously threaten the overall dam stability due to unrestricted water flow through the damaged power intake tunnel underlying the dam. In addition, the current water passage and power facilities must be relocated to allow for future seismic upgrades to the Strathcona Dam itself. As part of the new low level outlet design and construction, there is also the opportunity to construct a new power intake tunnel to be used when the existing intake is replaced in future seismic upgrades.

This project was initiated in F2015. The initial work determined alternatives for the new Low Level Outlet, including the sizing of the new discharge and options on how to safely discharge this flow through the Campbell River system. The future powerhouse and major dam upgrades are not part of this project. However, siting of a new powerhouse location was specifically included in this project to ensure that the layout would be compatible with the potential footprint for a future upgrade to the embankment dam.

Work had progressed into F2016, and assessments of the optimal invert elevations for the new Low Level Outlet, target drawdown rates/discharges, and the failure modes of the dam to determine the benefits of the Low Level Outlet were completed. Work in F2017 included:

- Selection of the preferred Low Level Outlet alignment on the right abutment and the preferred options which would involve a tunnel or a channel. This option will combine the spillway and low level outlet functionality, and will make it possible to significantly reduce the level of effort in upgrading the existing spillway for post-seismic operability,
- Completion of a conceptual design cost estimate, and
- Identification that the existing gated spillway structure could be converted into an Overflow Spillway structure. Together with the new Low Level Outlet, the two structures would retain the ability to safety pass the flows downstream into the Campbell River system, while greatly reducing the costs.

Therefore, a decision was made to include the spillway upgrades with the Low Level Outlet upgrades, to proceed as one project (with a name change to Discharge Upgrades).

Sugar Lake- Low Level Outlets

- ***Sugar Lake Dam – Gate Reliability***

This Project is originally part of the “Tier 2” Gate Program, which is intended to address only the more immediate concerns associated with deteriorated conditions and potential common cause failures associated with the low level gate system.

As the Project progresses, a potential opportunity have been identified that dam safety risks can be substantially addressed by modifying the current operation of stoplogs without capital improvement of the low level gate system.

This opportunity is being explored in Needs Phase, including its ramifications on conformance to the Water Use Plan.

Investigating unplugging techniques for cross-arm device

- ***W.A.C. Bennett – Core Casings Upgrade***

A number of open casings (observation wells, drillholes and cross-arm device) were installed in the core of the dam during construction and later, during sinkhole remediation. The water levels in some of the casings (the observation wells) have been observed to fluctuate and to suddenly drop indicating a potential for damage to the core of the dam. Annual geophysical measurements are carried out in some of these casings. As such, long-term access to the casings in the dam core is, and will continue to be, a valuable means of monitoring core performance.

This project was started in F2014 with the objective of:

- Eliminating the potential for damage and piping through the open vertically installed casings in the core of the dam, and
- Removing a stuck probe from the cross-arm devise and restoring its ability to continue with the crosshole geophysical measurements, if possible.

In F2016, the project was successful in grouting up the observation wells and selected drill hole casings in the dam core while installing piezometers or fibre optic cables in selected holes.

In F2017, the contractor was successful in unplugging a casing originally used for a cross-arm device that had been blocked for many years by a seismic hammer. The hammer was freed by over-reaming, and fell to the bottom of the casing. The remainder of the open casings, including this cross-arm device and the remaining selected drill holes will be grouted up in F2018.

Sand Flat Quarry Site, November 2016


Class 1 Rip Rap at Main Stockpile Area


Start of rip rap placement from left side of dam, March 2017

- ***W.A.C. Bennett – Rip Rap Upgrade***

Deterioration of the existing rip rap and resulting over-steepening of some sections of the upstream slope have been noted and monitored for a number of years. In F2012, the Rip Rap Upgrade Project was initiated to replace the deteriorated rip rap.

Work carried out in previous years included the identification of the preferred quarry site, Sand Flat, for the rip rap, and field investigations at this site to confirm the quality and extent of the rock available. A trial blasting program was completed at Sand Flat to provide additional information of the rock characteristics and the potential blast design for the production quarrying. Also, based on the trial blast results, the cost estimate was further refined. Work was also completed on the design of the rip rap, optimizing the cost with the rip rap design. Designs were finalized and the application to the British Columbia Utility Commission was submitted.

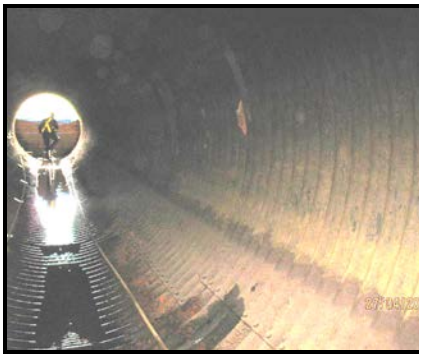
In early F2017, the British Columbia Utilities Commission and full project funding approvals were received, and the selected contractor mobilized to the site by August. Construction works started at the quarry, access roads were upgraded and a stockpile area close to the dam was created. During the first year of rip rap construction, the bedding and rip rap materials were first stockpiled over the fall/winter and then placed at the dam in late winter/early spring. Placement of year 1 of the rip rap at the dam was successfully started in March, continuing into May, as reservoir levels were kept low to accommodate the construction of the rip rap in the dry. Approximately 60% of the total rip rap (and bedding) were placed by May. Work will continue into F2018 to complete the construction.

W.A.C Bennett- Spillway Gates

- ***W.A.C. Bennett – Spillway Gate Reliability***

This is part of the "Tier 2" Gate Program, which is intended to address only the more immediate concerns associated with deteriorated conditions and potential common cause failures associated with selected electrical, mechanical, protection and control equipment. The intention is to provide a comparatively large increase in performance versus cost to achieve an acceptable balance between safety improvements and the investment made, by deferring broader scoped upgrades into the long-term future.

This Project is focussed on selected gate components above deck level only. This will include replacing defective drivetrain components (e.g. cracked pinions), adding a post-seismically operable diesel generator and other redundancies as appropriate. The Project is currently in Definition Phase.



Wahleach – tailrace tunnel, steel section

➢ ***Wahleach Dam – Tailrace Upgrade***

The primary objective of this project is to upgrade the existing tailrace tunnel to allow for a safe discharge of the powerhouse flows to the Fraser River without impacting the safety of the CN rail line or Highway 1. This project was initiated in F2016, with a number of viable alternatives consisting of tunnel relining were identified.

Work in in F2017 included:

- Inspection of the tailrace tunnel,
- Identification of a single viable alternative, which includes upgrades to the concrete by local repairs and by repainting of the steel section; and
- Hydraulic modeling of the tailrace tunnel with the selected options.

The planned preliminary design of the work is delayed, awaiting an opportunity for an investigation inside the tailrace tunnel, planned to coincide with a planned plant outage.

Wahleach, UT-SM9 at the Upper Tunnel lining break.

➢ ***Wahleach Dam – Instrumentation***

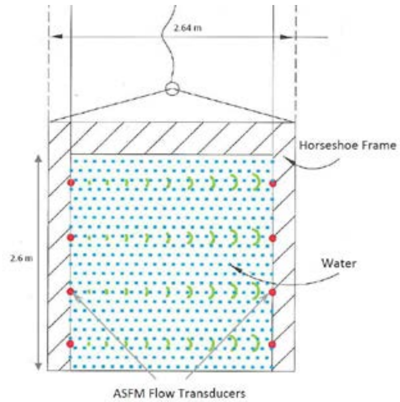
In January 1989, the deforming rock mass within the Wahleach slope pulled apart the steel lining in the horizontal portion of the upper tunnel. In addition 7 buckled zones were found in the inclined part of the power tunnel and one in the surge shaft. This incident initiated a major slope investigation and instrumentation program by Dam Safety. The portions of the original power conduit located within the deforming mass have been replaced by a new power conduit and operated for the first time in June 1992.

An array of boreholes and surface instruments was established on the slope to provide monitoring of its performance and of the power conduit conditions during power tunnel operations. Key instruments are connected to an automatic data acquisition system (ADAS). The functionality of the extensometers has been plagued with problems over the last several years. Efforts to rehabilitate these instruments were carried out in 2007 and 2011 with short term success. At this time, there is only instrument to provide real time monitoring of the movement of the Wahleach Slope, which is alarmed on a 24/7 basis. Considering the consequences to the powerhouse and the tight transportation corridor below the slope, redundancy in real-time measurement of the movement of the Wahleach slope needs to be re-established.

This project was initiated in F2017. The objective is to provide redundancy by installing an additional movement gauge at the lining break and to provide a larger area of slope movement monitoring coverage by installing 4 in-place inclinometers in 3 existing boreholes. These instruments will be connected to the existing ADAS.

This project is currently in a combined Identification and Definition phase. In Q1, the work included a site visit, the development of the options for another strainmeter and a look at the ADAS requirements for the new instruments.

The field work is targeted for August or September implementation.



Proposed Over-velocity Detection System

➢ ***Wahleach Dam – Over-velocity Detection Device***

The original mechanical over velocity detection (OVD) system at the Wahleach Lake intake was replaced by an electronic-based system in 1996, as the original system was unreliable, resulting in several false trips of the intake gate. However, the electronic OVD systems were plagued by several problems and operating issues, and taken out of service in 2003 due to false trips. The decision at that time was to fix and reinstate the old mechanical system, which has been in service since that time. In February of 2011, the mechanical system closed the intake gate in error as it was operating beyond the limit of its range. The Penstock Inlet Valve in the Valve House however did not close, and the unit was not shut down. As a result, the tunnel and penstock experienced a rapid de-watering which jeopardizes tunnel rock stability.

Given this risk, this project was initiated in F2017 to review and propose/implement upgrades to the OVD system at Wahleach intake. At this time, it is considered that the OVD at the Penstock Inlet Valve, which is a newer design, is adequate. Work completed in F2017 included the assessment of options for a new OVD device, with a recommendation for a new model device which measures the flow by the Acoustic Scintillation Method.


Walter Hardman

➢ ***Walter Hardman – Instrumentation***

Seepage exiting the toe of Walter Hardman Dam has been an ongoing issue. A decision to initiate a project to improve the monitoring and existing seepage collection system was made following a Dam Safety Team site visit in summer 2016.

Improvements to the seepage collection system were completed by BC Hydro's Construction Services in November 2016. Work included trenching at the toe of the dam, installing a slotted pipe backfilled with fine concrete aggregate and installing a weir box and a flume. Installation of the weir plate will be carried in F2018 and the weirs will be monitored using Dam Safety Automatic Data Acquisition System.

Projects Completed in Fiscal 2017 – Performance Investigations

Ladore Dam

➢ ***Ladore Dam – Seismic Stability***

Ladore Dam is a concrete gravity dam located downstream of Strathcona Dam and upstream of John Hart Dam. The dam has previously been upgraded to withstand a peak horizontal ground acceleration of 0.56g.

This project was initiated to assess the seismic performance of the dam for the updated seismic hazard of 0.68g. The screening level assessments of the dam and spillway structure have been completed. The project documentation was completed in F2017. The project concluded that the Ladore Dam structure can withstand the design earthquake loads, and upgrades are not required.

Active Projects – Performance Investigations

Cheakamus Dam

➢ ***Cheakamus Dam – Barrier Slide Failure Risk Assessment***

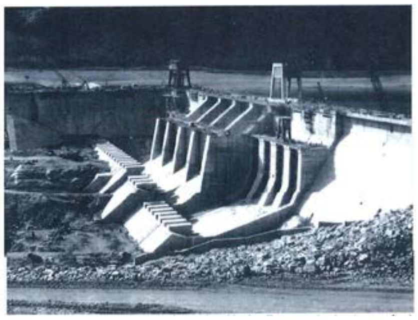
Cheakamus Dam is an extreme consequence dam with known seismic deficiencies. The overall objective of this study is to develop a dam safety risk management strategy for the Cheakamus Dam to address the identified deficiencies. Such overall risk management strategy has to take into account the risks that the potential Barrier Slide failure would pose to the dam and/or public safety downstream of the dam due the generated waves precipitated by a failure of the Barrier Slide. Identification of the risks posed by the Barrier Slide will inform future decisions regarding capital expenditures and the potential seismic upgrading of dam. This investigation was initiated in F2017 by evaluating the previous analyses and carrying out new analyses to provide more certainty on the impacts of a potential landslide on the dam and reservoir. This work will continue in F2018 with additional landslide and hydrotechnical analyses.

Coquitlam Dam

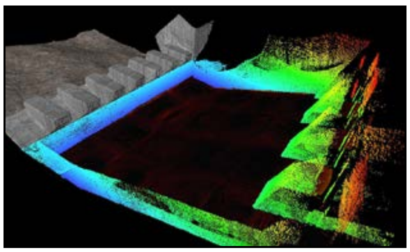
➢ ***Coquitlam Dam Data Compilation***

This investigation was initiated in F2016. The investigation included the compilation of the data and information on the design and construction of the new Coquitlam Dam which was completed in F2016.

The completion of a 3-D CAD model of the entire dam, including the original earthfill dam will be continued out in F2018.



Hugh Keenleyside Low-Level Outlets (right side of photo, taken after construction)



Underwater survey and quantification of concrete damages

➢ ***Hugh Keenleyside Dam – Low Level Outlet Operations***

Since operations began at Hugh Keenleyside Dam in 1968, concrete erosion has been occurring at the Low-Level Outlets, which, if left untreated, could compromise proper operation and maintenance of the facilities. Previous investigations indicate that the damage is likely due to both cavitation and abrasion, depending on the particular area.

This current investigation was initiated in F2015. The objectives of this study were to provide the following:

- An inspection methodology/schedule for immediate and long-term surveillance (structural and environmental),
- A concrete repair methodology, and
- An operational discharge sequence for the Low Level Outlets and spillways such that the dam can be operated sustainably, both structurally and environmentally into the future.

Work carried out in F2017 included:

- Underwater survey of the North Ports, and quantification of concrete damages,
- Hydrotechnical modelling of water discharges from spillways and low level outlets,
- Documentation of the operational and damage history, and
- Continuation of the field measurement of the total dissolved gas in water and updating the predictive equations for the total dissolved gas.

La Joie- South Conduit

➢ ***La Joie Dam – Seismic Performance of Water Passage System***

La Joie Dam is classified as an extreme consequence dam under the British Columbia Dam Safety Regulation. One of the key dam safety issues identified is to secure high reliability post-earthquake operational control of the reservoir. Low level discharge is provided by both the south conduit (power generation and bypass) and the north conduit (controlled by hollow cone valves). Previous work has been completed to improve the seismic performance of the north conduit, including the installation of new hollow cone valves.

The objective of this project is to determine the earthquake level for which post-seismic operability of the south conduit can be expected, to determine the level of concern at which discharge may be impacted. This project was initiated in F2017. The work included a site visit by the team, followed by dynamic analysis of the south conduit. This work is targeted for completion in F2018.

Spillway and Outlet Works Flip Bucket

➢ *Mica Dam – Seismic Performance of Select Components of Spillway and Outlet Works*

Mica Dam is the largest and most upstream of the three dams built on the Columbia River and its tributaries in British Columbia. The Mica Dam facility consists of an embankment dam, ogee weir spillway, radial gates, intake tower, water conveyance conduits and a powerhouse.

The objective of this project is to assess the seismic performance of select components of the Mica spillway and outlet works. The assessments shall be completed on the basis of ensuring post-maximum design earthquake operability of the spillway and outlet works. This project was initiated in F2017 with development of a design plan. The seismic assessment of the select components will be carried out in F2018.

Mica Dam – downstream slope

Mica Dam – aerial view

➢ *Mica Dam – Special Investigations - Long Term Performance*

A Special Investigations project for large embankment dams was initiated in 2011, starting with the WAC Bennett Dam (see below for description of the work at the WAC Bennett Dam). As part of this investigation, the next dam to assess is the Mica Dam. The work on Mica started in F2016. The overall objective of this project is to carry out a detailed performance assessment of the dam by compiling the construction and investigations data and to prepare a site characterization of the dam and foundation materials, and using this data to develop, test and verify numerical models of the dam to assist in predicting the dam performance. The work will provide a good understanding of the current condition of the dam as well as a developing a set of monitoring and response systems that can be utilized for dam safety management decisions and activities.

Work completed since F2016 include compiling of the background information, plotting and analyzing of the instrumentation data, and starting the development of a 3-D CAD/GIS model. The first Expert Engineering Panel meeting was held in August 2016. 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, where the zone where the filter does not extend up to flood level. 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. In particular :

- The Expert Engineering Panel considers the hazard presented by a potentially rapidly moving landslide from Dutchman's Ridge, Little Chief Ridge or Little Chief Slide to be important
- A seismic deformation and stability analysis should be performed of the dam and its appurtenant structures
- Special attention should be paid to the deformations and stability of the retaining wall at the left abutment adjacent to the spillway during the Safety Evaluation Earthquake.

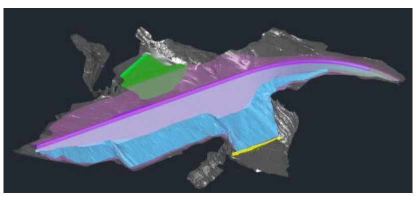
Based on the recommendations, the work plan for F2017 was developed, prioritizing the collection of dam fill materials required for large scale laboratory testing (planned in future years) and the continuation of the data compilation/processing required to carry out the site characterization. This work is planned for F2018.


Strathcona Dam

➢ ***Strathcona Dam – Seismic Performance Assessment***

Several alternatives, and sequencing of these alternatives, have been considered for the future upgrades of the Strathcona facility. Construction of a new low level outlet has been identified by Dam Safety as a priority to minimize dam safety risks, and this capital project is currently in progress. The necessary upgrades for the dam, however, have not yet been determined. The purpose of this investigation project is to assess the potential performance issues associated with the embankment dam and to determine what upgrades, if any, are required to ensure the long-term performance.

This investigation will be carried out in multiple phases over a number of years. The first phase consists of compilation, and review of all existing information on dam fill and foundation characterization. The compilation of the background information and the relevant documentation for this activity were started in F2017. Based on the available information, the scope of the F2018 work will be developed.


3-D CAD model of WAC Bennett Dam

➢ ***W.A.C. Bennett – Special Investigations, Embankment Dam***

The objective of this project is to better understand the current performance of the dam, to improve the performance monitoring tools and to develop risk management strategies/plans to ensure continued, safe operation of the dam.

This project was initiated in F2011, as part of the Special Investigations initiative for large embankment dams. Initial work included review of the construction and performance data, initiating the development of a digital 3D model of the dam and foundation, and presentation of the work to a three-member Expert External Engineering Panel at three meetings, culminating in their report. In general, the Expert Engineering Panel concluded:

- *The dam was well designed for the time it was constructed and the extensive construction testing indicates it was well constructed.*
- *The standard of monitoring and surveillance of the dam is extremely high and those involved clearly understand the dam and its performance.*
- *The dam has a good filter system consisting of the Transition, the Filter and Drain, which may allow a small amount of erosion at the Core / Transition interface, but from the available information, will prevent on-going erosion.*

The panel made a number of recommendations for further data review, compiling of the construction and instrumentation data, further analyses for seepage, stresses, filtering, cementation, seismic analyses, etc. for the ongoing confirmation of adequate performance of the dam.

The Expert Engineering Panel was reconvened in F2016 to review the results from the past 3 years of work by BC Hydro. It stated in their 2nd report *that the work undertaken by BC Hydro over the past 3 years confirms their 2012 conclusions on the satisfactory condition of the dam, and that the filtering system at the WAC Bennett Dam would prevent erosion in normal seepage* *flows.*

The EEP agrees that, although the overall dam will remain stable following the design earthquake, the upper part of the dam may be vulnerable to deformations and cracking under seismic loads. However, this situation would only be a concern after an extreme seismic event in combination with a series of conditions that the EEP considers as highly unlikely.

BC Hydro intends to prioritize the additional studies and laboratory tests suggested by the EEP and carry these out in future studies. The results, along with the other dam performance information, will assist BC Hydro in making a properly informed decision in regard to possible future remedial works.

In F2017, work was focused on the developing methods to better interpret the cross-hole shear wave velocity data, verifying the cracking potential of the Transition and Filter, and assessing the long term instrumentation requirements. A new capital project will be initiated in F2018 to implement the long term instrumentation upgrades. Work will continue on the performance assessment of the dam.

Projects Completed in Fiscal 2017 – Initiatives

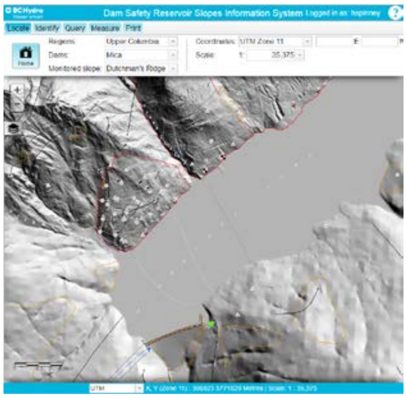
Croil Lake

- ***System-Wide – Water Licence Dams***

BC Hydro carried out a records search of all BC Hydro water licences to determine whether liabilities exist due to small water retaining structures. This work led to the decommissioning of the Finney Lake and Sturdy Creek Dams over the past few years.

BC Hydro holds water licences for purposes other than power production, on lakes that have been dammed by others. The new BC Dam Safety Regulation has provided clarity on dam ownership and further clarity was provided by BC Hydro's Legal Services in relation to decommissioned dams. The list of dams owned by BC Hydro is listed in the Dam Safety Governance Manual, along with the responsibilities of BC Hydro.

Active Projects – Initiatives

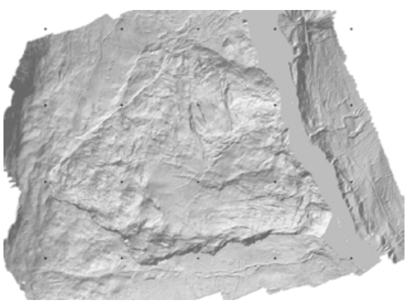


➢ *GIS Information Management*

BC Hydro is undertaking a project to implement a unified Geographic Information System (GIS) for dam safety information. The GIS based information system will provide a single access point to GIS and other BC Hydro information systems for dam safety. Information such as instrumentation data, Dam Safety issues, construction documents, water passage status, weather and performance model output will be accessed from the new interface.

The reservoir slopes portion of the GIS is now in full production mode and is populated with most of the Upper Columbia landslide information. It provides access to instrumentation information, documentation and bare earth visualization based on LIDAR data. The first draft of the Dam Safety GIS Standards has been completed.

Work to expand the system to include dams and access to other BC Hydro information systems has been delayed due to the resignation of key personnel.

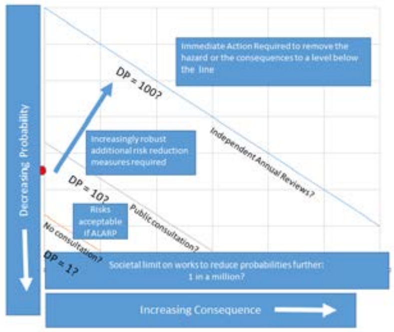


LiDAR image Downie Slide

➢ *Remote Sensing for Landslides*

This project aims to implement the use of remotely sensed 3D data to improve coverage, accuracy and usability of information for landslide identification and monitoring, thereby improving management of the risk associated with landslides. It is expected that the project will provide an improved understanding of landslide activity and the associated risks to the dams and reservoirs.

F2016 Remote Sensing of landslides concentrated on a second scan of Downie Slide to compare with the initial scan obtained in 2009. Unfortunately the scan quality obtained in F2016 did not allow a comparative analysis. This has led to a scrutiny of data collection methodologies to ensure future work is successful. F2017 work involved a project with industry specialists in remote sensing to develop a plan for F2018 data collection and change detection remote sensing. The initial stage of this work was completed in F2017. Data collection at a targeted site is planned for F2018.



Some of the factors in societal risk tolerance

➢ *Tolerability of Risk*

The 10-year Capital Plan defines a level of safety for the portfolio of dams that is to be achieved during the life of the plan. Those risks not possible to address within existing constraints are being managed through various risk management plans.

The concept of phased improvement in the safety of dams (with appropriate risk controls) and resulting implied level of remaining risk is the accepted norm in the industry. However, modern societal expectations increasingly involve demonstration of the appropriateness of the resulting level of risk control for installations such as dams. The approach to controlling risk within limits must also be demonstrated for general acceptability (including Regulatory, Legal and Societal aspects) in the Canadian context.

In order to address the matter of how BC Hydro will demonstrate the suitability of its approach to the level of risk control, this initiative is progressing along a dual path comprising; development of a generalized stakeholder analysis framework, and performing a Canadian/British Columbia context analysis for risk decisions involving societal interests and concerns, with specific reference to dams. Both of these paths, which will converge in the coming year, are building on the experiences of the Campbell River and Jordan River seismic risk consultative processes.

Strategic Issues and Other Initiatives

Interim Risk Management Initiatives

- ***Vancouver Island Seismic Resilience***

Dam Safety is leading a Corporate initiative to better understand the probabilities and consequences of overall damage to the electrical supply system for Vancouver Island. Previous damage assessment work for the key Transmission assets has now been re-run with new input that incorporates the results of the 2012 Probabilistic Seismic Hazard Analysis project. This has allowed the potential risks to be better quantified. Work is ongoing to expand the model to include Generation and some key Distribution assets. Later stages will use these results to develop proactive and reactive plans for system recovery following a major seismic event.

General Initiatives

- ***Discharge Function Integrity Project***

BC Hydro's work with the Swedish Electricity Industry's Research company Energiforsk, Ontario Power Generation and US Army Corps of Engineers on developing a new scientific framework for the analysis of spillway function reliability and availability has culminated in a published book, *Operational Safety of Dams and Reservoirs,* that reflects the results of this collaboration.

BC Hydro is continuing this initiative through a training and development arrangement with Western University in London, Ontario. The focus is on further developing the more theoretical dimensions of the modeling concept exemplified in the book, while ensuring compatibility between theory and implementation. BC Hydro personnel Des Hartford and Derek Sakamoto, supported by other staff and capabilities, are participating directly in this work.

Dam Safety Practices and Learned Societies

- ***Canadian Dam Association (CDA)***

BC Hydro staff continued to work with the Dam Safety Committee of the Canadian Dam Association, in particular on completion of a Technical Bulletin on Dam Safety Reviews and development of a workshop on this topic and fostering risk-informed decision making.

- ***International Commission on Large Dams (ICOLD)***

BC Hydro is a member of three committees: Dam Safety, Hydraulics and Seismic, and is also a contributor to the work of the Committee on Floods. BC Hydro is heavily involved in the ongoing work to develop guidance on *Dam Safety Management in all phases of the Life-cycle prior to Operation* (having been similarly involved in developing the guidance on *Dam Safety Management in the Operational Phase of the Life-cycle*). The Committee on Dam Safety has two other working groups on Risk Assessment and Dam Failure Consequence Assessment, and BC Hydro is also centrally involved in these two working groups. These latter two activities have revealed marked differences in practices, approaches and philosophies between countries, with the Netherlands applying the most resources and the most rigorous analytical approaches in the domain of risk assessment. Properly clarifying the differences in practices and identifying the reasons for these differences will be an important part of strengthening the acceptance of the "Risk-informed" approach to dam safety that is being pursued at BC Hydro.

- ***CEATI – Dam Safety Interest Group (DSIG)***

BC Hydro is one of more than 50 member dam owners of the DSIG, which provides a forum for discussion of topics of mutual interest, and sponsors specific initiatives in dam safety. BC Hydro continues to be involved in work being carried out in the areas of dam anchoring, lessons learned in dam safety incidents and methods for self-evaluation of overall effectiveness of dam safety programs. The Dam Safety group will be undertaking a major self-evaluation using the CEATI methodology in the coming year.

Business Summary

The progress of dam safety activities over the fiscal year, compared to the plan, is shown on the table below.

Dam Safety Program Costs versus Plan *($M)*

	F2017 Plan	*F2017 Actual*
Performance Investigations	2.40	2.59
Surveillance	4.20	3.95
Regulatory, Risk, Other Program Activities and Administration	2.85	3.00
Departmental budget[1]	9.45	9.54
Capital improvements[2,3,4,5]	99.96	122.61

Notes

1. *Includes Special Investigations Embankment Dams -WAC Bennett and Mica ($0.7M F2017 Plan and $1.15M F2017 Actual, see Table 2, Appendix C).*
2. *Capital improvements cover dam safety initiated projects and the dam safety portion of the Ruskin Dam and powerhouse upgrade project.*
3. *Salmon River Refurbish Dam & Canal Project spending ($0.82 M) is not included in F2017 Actual.*
4. *Spending on project completion/documentation for Stave Falls Spillway Gates Upgrades ($0.20M) and Revelstoke Left Bank Instrumentation ($0.15M) are not included in F2017 Actual.*
5. *The variance is mainly due to the WAC Bennett Dam Riprap project.*

Appendix A:
BC Hydro Dams

DAM SITE	CONSQ. [1]	TYPE [2]	# OF DAMS	YR.	HT. (m)	GENERATING STATION	RESERVOIR/HEADPOND	RES. AREA (ha)
Aberfeldie	H	PG	1	1953	32	Aberfeldie	Aberfeldie Headpond	-
Alouette	EX	TE	1	1926	21	Alouette	Alouette Lake Reservoir	1600
Bear Creek	L	TE	1	1958	19	Jordan River	Bear Creek Reservoir	75
Buntzen	S	PG	1	1903	16.5	Buntzen 1 & 2	Buntzen Lake Reservoir	185
Cheakamus	EX	TE/PG	5	1957	29	Cheakamus	Daisy Lake Reservoir	4300
Clayton Falls	S	PG	1	1961	7	Clayton Falls	Clayton Falls Headpond	-
Clowhom	S	PG	2	1958	22	Clowhom	Clowhom Lake Reservoir	800
Comox	EX	PG	1	1912	10.7	Puntledge	Comox Lake Reservoir	3000
Coquitlam	EX	TE	1	1914	30	-	Coquitlam Reservoir	1250
Duncan	EX	TE	1	1967	38.7	-	Duncan Reservoir	7150
Durack Brook	S	TE	1	1963	4.5	-	Durack Brook Reservoir	0.2
Elko	S	PG	1	1924	16	Elko	Elko Headpond	-
Elliott	VH	PG	1	1971	27.4	Jordan River	Elliott Headpond	-
Elsie	EX	TE	6	1958	31	Ash River	Elsie Lake Reservoir	658
Falls River	S	PG	1	1930	13	Falls River	Bigs Falls Headpond	-
Hugh Keenleyside	EX	TE/PG	2	1968	58	-	Arrow Lakes Reservoir	51 600
John Hart	EX	TE/PG	4	1947	34	John Hart	John Hart Reservoir	250
Jordan Diversion	VH	CB	1	1913	39.9	Jordan River	Jordan Diversion Reservoir	168
Kootenay Canal	VH	PG/ER	8	1975	38	Kootenay Canal	Kootenay Canal Headpond	-
La Joie	EX	ER	1	1948	87	La Joie	Downton Reservoir	2400
Ladore	EX	PG	3	1949	37.5	Ladore	Lower Campbell Lake Reservoir	3700
Mica	EX	TE	1	1972	244	Mica	Kinbasket Reservoir	42 500
Peace Canyon	VH	PG	2	1979	61	Peace Canyon	Dinosaur Reservoir	890
Puntledge Diversion	VH	PG	1	1912	5.5	Puntledge	Puntledge Headpond	-
Quinsam Diversion	S	PG	1	1957	15	Ladore	Quinsam Diversion Headpond	-
Quinsam Storage	S	PG	1	1957	9	Ladore	Upper Quinsam Lake Reservoir	564
Revelstoke	EX	TE/PG	4	1984	175	Revelstoke	Revelstoke Reservoir	11530
Ruskin	EX	PG	1	1930	59.4	Ruskin	Hayward Lake Reservoir	300
Salmon River Diversion	L	ER/T	1	1957	5.5	Ladore	Salmon River Headpond	-
Seton	H	PG	3	1956	13.7	Seton	Seton Lake Reservoir	2460
Seven Mile	EX	PG	1	1980	80	Seven Mile	Seven Mile Reservoir	410
Spillimacheen	S	PG	2	1955	14.5	Spillimacheen	Spillimacheen Headpond	-
Stave Falls	EX	PG	2	1911	26	Stave Falls	Stave Lake Reservoir	6200
Strathcona	EX	TE	2	1958	53	Strathcona	Upper Campbell Lake, Buttle Lake Reservoir	6680
Sugar Lake	EX	CB	1	1942	13.4	Shuswap Falls	Sugar Lake Reservoir	2100
Terzaghi	EX	TE	1	1960	60	Bridge River 1 & 2	Carpenter Reservoir	4800
W.A.C. Bennett	EX	TE	1	1968	183	GM Shrum	Williston Reservoir	117 000
Wahleach	VH	TE	1	1953	21	Wahleach	Jones Lake Reservoir	490
Walter Hardman	S	TE	6	1960	12	Walter Hardman	Walter Hardman Headpond	-
Whatshan	S	PG	2	1951	12	Whatshan	Whatshan Lake Reservoir	1700
Wilsey	H	VA	2	1929	30	Shuswap Falls	Wilsey Headpond	-

[1] Consequence Categories: EX extreme, VH very high, H high, S significant, L low
[2] Main dam at site: PG concrete gravity, CB concrete buttress, VA concrete arch, TE earthfill, ER rockfill, ER/T rockfill timber crib.

Appendix B:
Dam Safety Advisory Boards for Ongoing Projects

PROJECT	NAMES	MEETING NO.	DATE
John Hart	Mr. J. France (USA))	1	Aug/Sept 2015
Seismic Upgrades	Mr. D. Johnston (USA)	2	July 2016
	Dr. Y. Ghanatt (USA)		
	Dr. G. Grilli (New Zealand		
Ruskin			
Seismic Upgrades	Dr. R. Hall, USA	1	September 2002
	Mr. J. France, USA (added in 2003)	2	August 2003
	Dr. Georges Darbre, Switzerland (April 2008 only)	3	August 2004
		4	April 2008
	Mr. Ron Monk (April 2008 only)	5	November 2008
	Mr. Joe Ehasz (added in 2009)	6	November 2009
		7	September 2011
		8	June 2012
		9	May 2013
		10	May 2014
		11	November 2015
		12	Nov/Dec 2016
Strathcona			
Seismic and Seepage Upgrades	Dr. J. France, USA	1	January 2003
	Dr. Y. Ghanaat, USA	2	January 2006
	Dr. S. Alam, France (added in 2006)	3	December 2007
	Mr. J. Kelly, USA (added in 2007)	4	October 2008
	Project was put on hold pending finalization of overall dam safety strategy for the Campbell River System; and the Board will be re-instated shortly.		
W.A.C. Bennett			
Dam Performance -Surveillance	Dr. E. DiBiagio, Norway (External Reviewer)	1	September 2001
		2	December 2002
		3	March 2004
		4	March 2005
		5	March 2006
		6	April 2007
	Mr. R. Peggs	7	December 2009
	Expert Engineering Panel (below)	8	August 2012
Spillway Chute-Long-term Issues	Dr. Peter Mason	1	July 2013
Expert Engineering Panel (WAC Bennett and Mica)	Dr. K. Hoeg, Norway	1	March 2011
	Mr. R. Bridle, UK	2	July 2011
	Dr. R Fell, Australia	3	February 2012
		4	November 2015
		5	August 2016
BC Hydro System			
Gate reliability upgrades	Dr. Geoff M. Ballard, New Zealand	Ongoing advice	2007 - present

Appendix C:
List of Projects

Table 1: Dam Safety Improvement Projects

$ Thousands

		Actuals (Current Year)	Total Actuals (To Date)
Active			
General Capital			
Alouette	Seismic Upgrade	342	381
Bridge River I	Penstock Leak Detection and Protection	786	6,152
Bridge River I	Slope Drainage Improvement	219	826
Bugaboo Diversion	Decommissioning	166	178
Comox- Puntledge	Flow Control Improvements	550	1,585
John Hart	Seismic Upgrade	4,112	9,119
Jordan	Mitigate Seismic Risk	5,394	10,935
Ladore	Spillway Seismic Upgrade	546	943
Revelstoke	Marble Shear Block	42	1,416
Ruskin	Seismic Upgrade	32,307	196,631
Salmon River	Decommissioning	908	908
Strathcona	Discharge Upgrades	1,135	1,641
WAC Bennett	Core Casings Upgrade	1,292	3,727
WAC Bennett	Rip Rap	52,596	62,776
Wahleach	Tailrace Replacement	398	438
Wahleach	Instrumentation	39	39
Wahleach	Intake/Penstock Upgrade (Over velocity Detection Device)	63	73
Various Sites	Debris Booms	1,147	2,330
Various Sites	Rock Correction for Seismic Hazard	78	1,165
Spillway Gates			
Clowhom	Spillway Gates & Diesel Generator	38	140
Peace Canyon	Spillway Gates Upgrade	1,184	4,250
Sugar Lake Dam	Spillway Gates Upgrade	28	145
WAC Bennett	Spillway Gates Upgrade	1,729	7,114
	TOTAL	**105,909**	**312,912**
In-Service/Completed/Closed			
General Capital			
Duncan	Core Cutoff Wall Installation	1,695	1,800
Duncan	Instrumentation Improvements	311	5,517
WAC Bennett	Spillway Chute	11,746	23,134
Spillway Gates			
Hugh Keenleyside	Spillway Gates Upgrade	3,763	111,393
	TOTAL	**17,515**	**141,844**
	TOTAL (Active, In-Service/Completed/Closed)	**122,614**	**454,756**

Table 2: Performance Investigations

		$ Thousands	
		Actuals (Current Year)	Total Actuals (To Date)
Active			
Cheakamus	Barrier Slide Failure Risk Assessment	58.9	58.9
Coquitlam	Data Compilation	60.7	149.1
Hugh Keenleyside	Low Level Outlet Operations	177.6	493.1
La Joie	Seismic Performance of Water Passage System	144.0	144.0
Mica	Spillway Seismic Performance Assessment	24.1	24.1
Special Investigations, Embankment Dams (WAC Bennett-Mica)	Performance Assessment	1,158.7	4,248.0
Strathcona	Seismic Performance Assessment	40.7	40.7
System wide	Columbia River Flood Hazard Assessment	306.9	312.2
System wide	GIS Information Management	165.2	327.9
System wide	Remote Sensing for Landslide Detection	72.3	328.0
System wide	Tolerability of Risk	231.8	549.2
	TOTAL	**2,441.8**	**6,675.3**
Completed			
Ladore	Seismic Stability	15.6	479.1
Peace Canyon	Seismic Stability	33.7	242.3
System wide	Reservoir Level Monitoring and Gates Heating	43.1	174.0
Terzaghi	Seismic Stability	60.8	1,256.4
	TOTAL	**202.4**	**2,445.0**
	TOTAL (Active and Completed)	**2,594.9**	**8,827.1**