2015–2016
Dam Safety Report

Dam Safety Program Report 2015 – 2016 (F2016)

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Overview

BC Hydro currently owns, operates and maintains 79 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 B.C. 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, 2016.

Contents

Introduction

BC Hydro's dams

BC Hydro currently owns, operates and maintains 79 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 British Columbia 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 British Columbia 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.

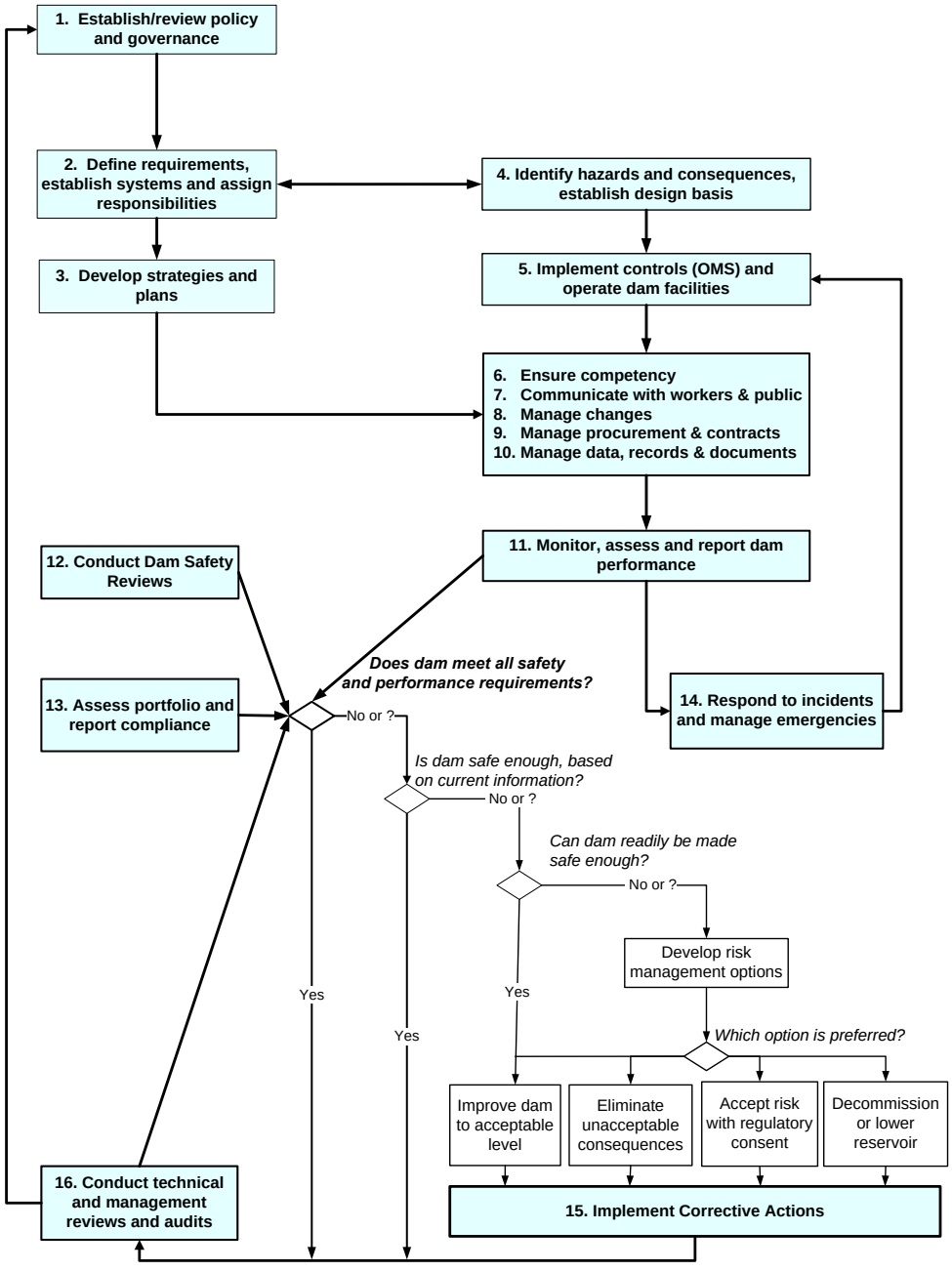
BC Hydro's Dam Safety Management System

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.

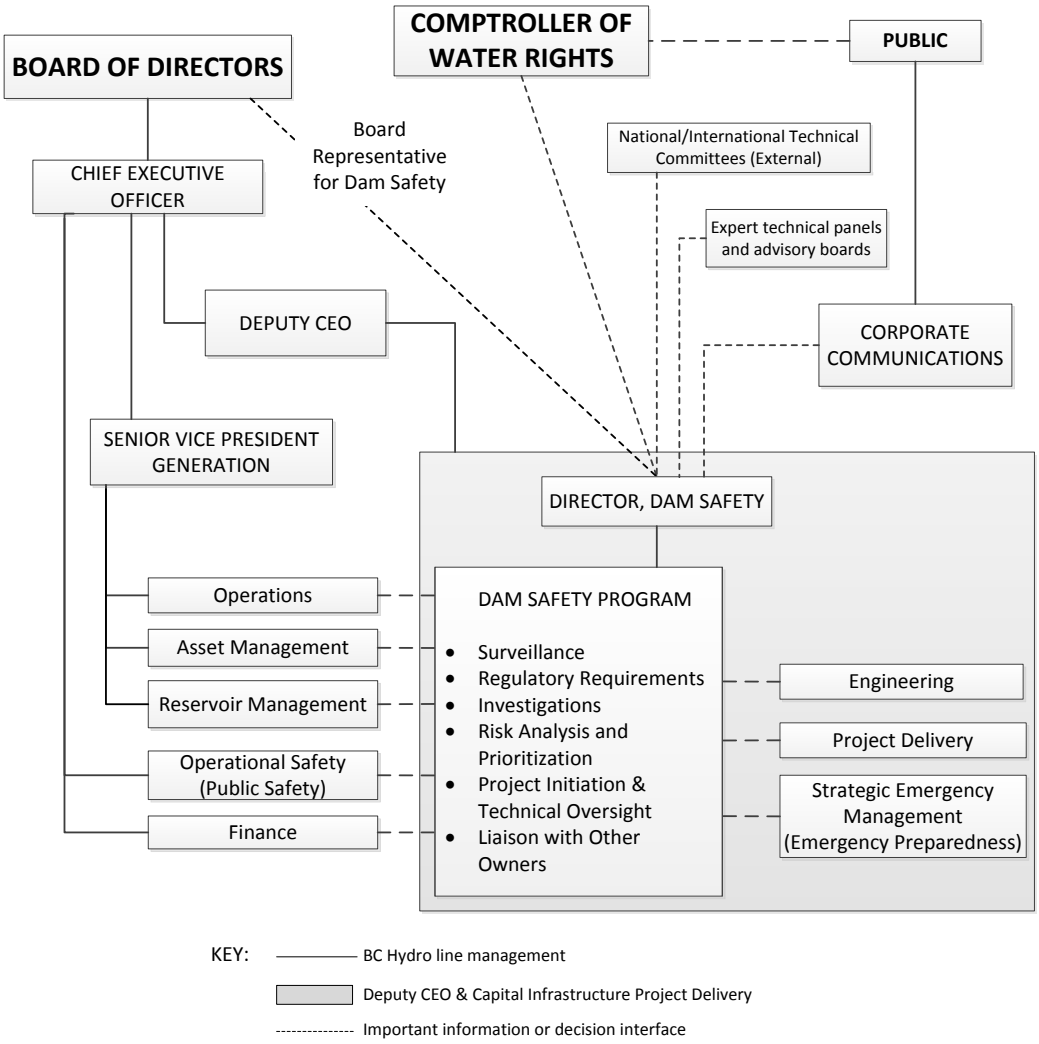
The key elements of the Dam Safety Management System are illustrated in the figure below.



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.



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 whom 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 #1 was held in August/September 2015. 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 gates. At this first meeting, the Board was provided with a site tour, the background studies leading to the capital upgrades, conceptual options for the Middle Earthfill Dam, the North Earthfill Dam, the Concrete Dam and Gates, and the layout for a new passive spillway. The Board confirmed BC Hydro's conclusion that a seismic upgrade of the John Hart Dam was required and provided some comments on the conceptual designs.

In November 2015, the Ruskin Dam Advisory Board was convened to provided advice on the ongoing construction of the upper part of the dam and on the seismic analyses of the dam. This was the 11th Advisory Board Meeting, and the Board provided timely advice on the staging of the bulkhead move and commissioning of the new Gates 1 and 2 as well as endorsing the work completed to date on the dam analyses.

In November 2015, the 4th Expert Engineering Panel (EEP) Meeting to discuss the ongoing GMS Embankment Performance was convened. This was the first meeting convened in 3 years, and the Panel prepared their 2nd report. At this meeting, the results from the additional analyes, laboratory testing and field investigations were presented, addressing recommendations from their 1st report (issued in 2012). The EEP states 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. In response to their concern, as noted in their 2012 report when the EEP questioned the effectiveness of the upper part of the dam in resisting internal erosion, BC Hydro has now completed a number of assessments that indicate that this would not be a concern under normal conditions. BC Hydro has also completed a seismic assessment of the dam. The EEP agrees that, although the overall dam will remain stable, 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.

Dam Risk Management

Management System

The dam safety management system is described in detail in the Dam Safety Governance Manual, available on the BC Hydro Intranet. 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.

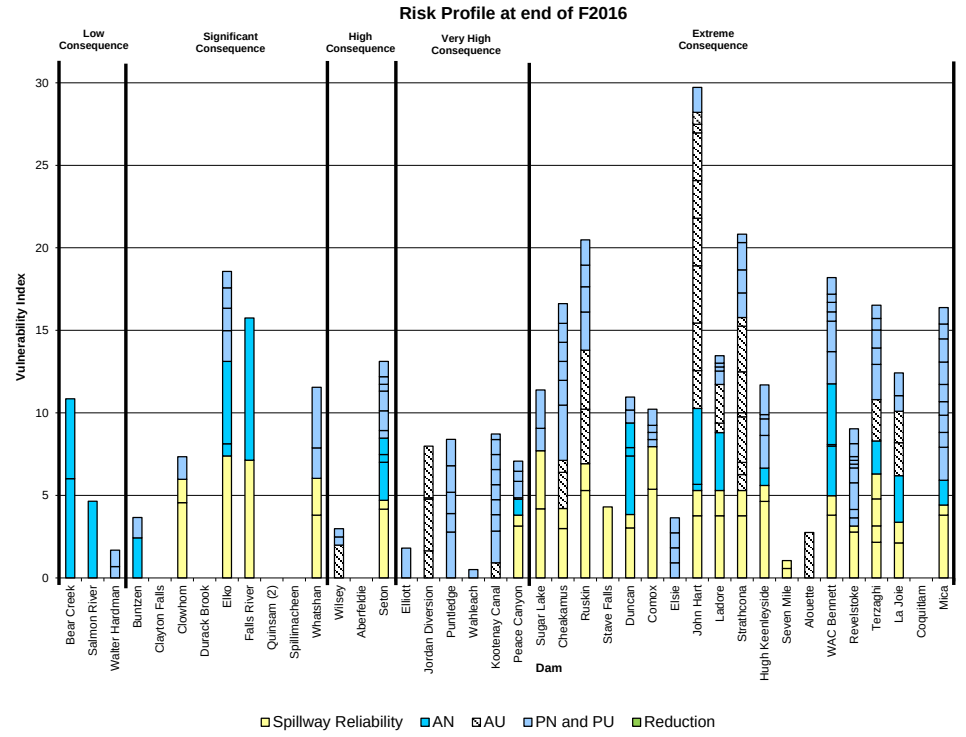
The term "risk" is used here in a general sense; it is not a direct measure of the probability of failure multiplied by the consequences. Although desirable, dam risks cannot yet be reliably quantified.

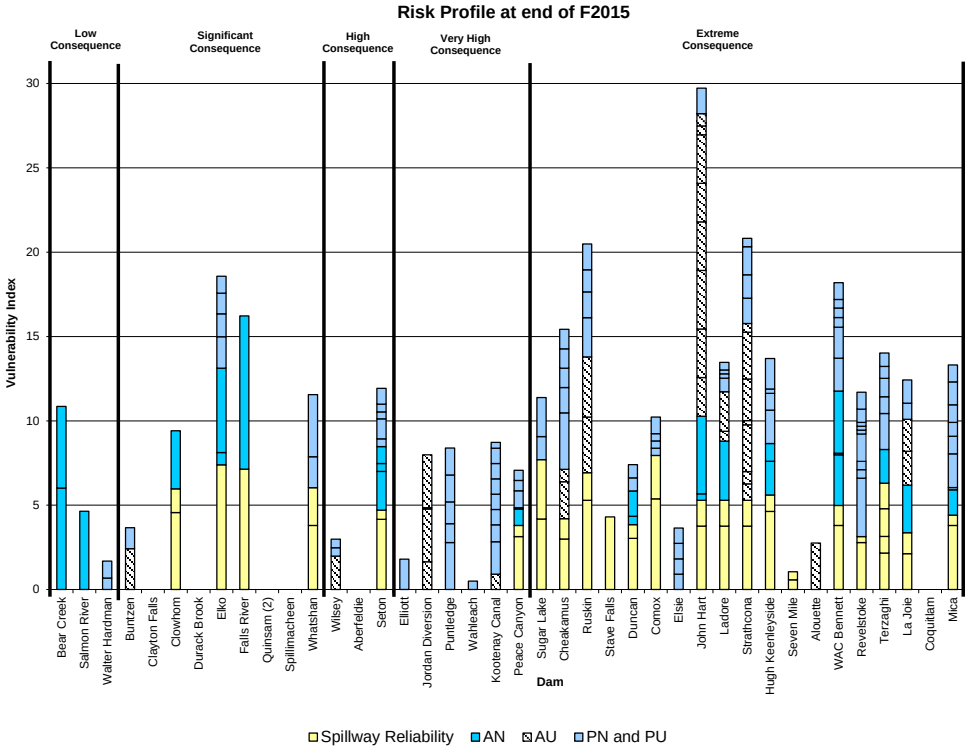
Risk Profile

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



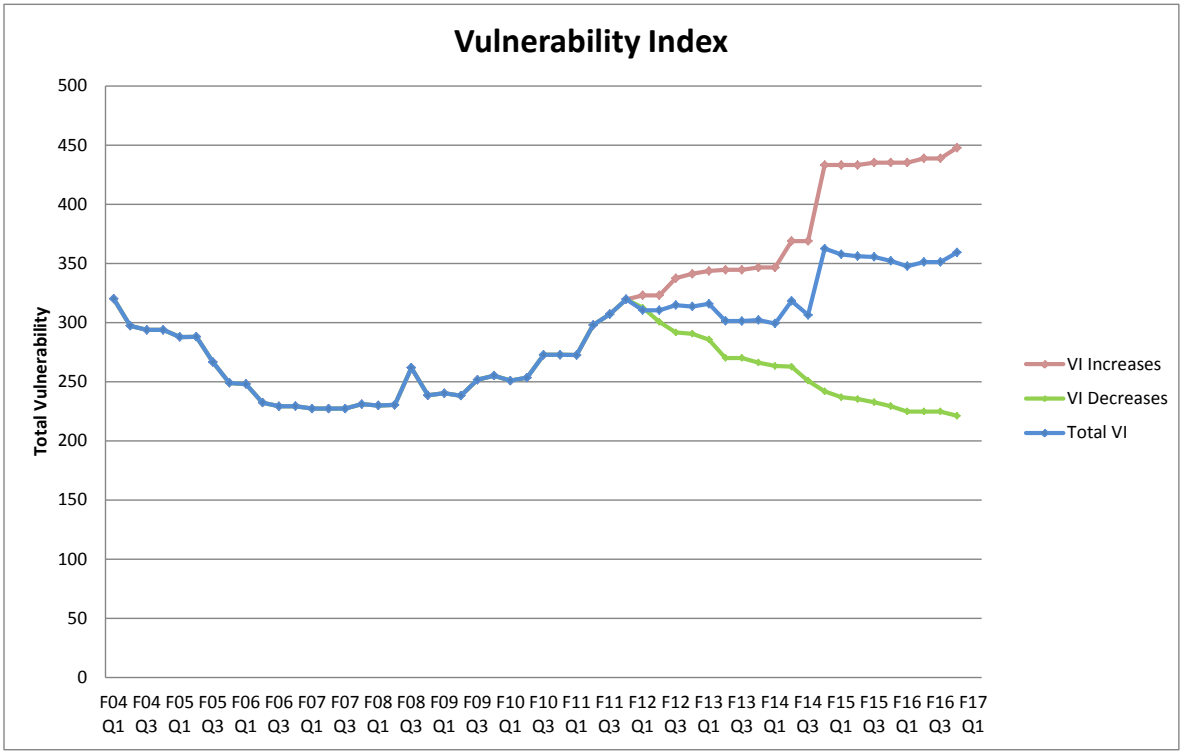


Legend:

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 increase in the VI this past year due to increases at Duncan, Mica, Cheakamus, Seton, and Terzaghi Dams (see Figure 1); these have been partially offset by VI decreases at Clowhom, Hugh Keenleyside, and Revelstoke Dams.

The VI increase at Duncan Dam was due to the discovery that the top elevation of the effective impervious core in Duncan Dam is lower than designed. Slight increases at Mica, Cheakamus, and Seton are due to the estimates of the vulnerability of these dams to overtopping waves from landslides. The VI increase at Terzaghi is due to the vulnerability associated with the lack of a means to cutoff flow from the Bridge River 1 penstocks in the event of a penstock breach.

The small decrease at Clowhom in F2016 is due to the fact that the temporary change in consequence classification considered in F2015 (due to workers being temporarily located downstream from the dam) is no longer applicable. The decrease at Hugh Keenleyside dam is due to the completion of a berm on the abutment immediately downstream from the dam. The VI decrease at Revelstoke is due to the re-rating of an identified deficiency which was discovered to be due to the piezometers malfunctioning.

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, 2016 (end Fiscal 2015) 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
Comox – Puntledge	Flow Control Improvements	In-progress
Hugh Keenleyside	Gate Reliability Upgrades	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
Ruskin	Seismic Upgrade	In-progress
Revelstoke	Marble Shear Block	In Progress
Salmon River	Refurbishment Canal and Dam, and Install Fish Passage	In-progress
Sugar Lake	Gate Reliability Upgrades	In-progress
W.A.C. Bennett	Gate Reliability Upgrades	In-progress
W.A.C. Bennett	Spillway Chute	In-progress
W.A.C. Bennett	Rip Rap	In-progress
W.A.C. Bennett	Core Upgrade	In-progress
Strathcona	Low Level Outlet Seismic Upgrades	In-progress
Wahleach	Tailrace Upgrade	In-progress
Duncan	Installation of Core Cutoff Wall	In-progress
System Wide	Rock Correction of Seismic Ground Motions	In-progress
Duncan	Instrumentation Improvements	Completed
La Joie	Interim Risk Management	Completed
La Joie	Water Passages Upgrades	Completed
Revelstoke	Left Bank Instrumentation	Completed
Ruskin	Right Abutment Seepage Control	Completed
Wilsey	Instrumentation and Access Upgrade	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 2016 as listed below. Descriptions of the work undertaken are given in the Project Activities section of this report.
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	Dam	*Possible Issues*
Investigations Underway		
	Hugh Keenleyside	Low Level Outlet Operations
	Ladore	Seismic Stability
	W.A.C. Bennett	Special Investigations – Embankment dam
	Coquitlam	Data Compilation
Completed Investigations Fiscal 2016		
	Campbell River System	Evaluation of Increased Flood Passage Capability
	Campbell River System	Flood Estimations
	Terzaghi	Seismic Performance of Embankment Dam
	Kootenay Canal	Seismic Stability
	Puntledge	Life Safety Model
	Duncan	Downstream Inundation Assessment

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	Remote Sensing for Landslides
	System wide	Tolerability of Risk – development of a decision framework
	System-wide	Water License Dams – review of corporate responsibilities at small dams where ownership/licenses may be shared with other entities

Regulatory Activities

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

Site Surveillance

A total of 1593 or 98.8% of inspections were completed in F2016. Nineteen scheduled inspections were missed due to weather-related access difficulties or unavailable personnel. There have been no two successive missed inspections.

Formal Dam Inspections

Annual or semi-annual surveillance inspections and reports were completed for all dams for F2016 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

Spillway gates required for passing the design floods were inspected and tested, and exceptions noted in the annual compliance report for each dam.

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 tests were undertaken in F2016, covering all spillway gates in the BC Hydro system. Those gate systems that have been upgraded under the Spillway Gate Reliability Program encountered fewer gate operational failures than in the past, and in comparison to other sites. Due to the additional redundant components at these sites, more partial failures (i.e. where gates remained operable but certain lines of defense failed) were being recorded in monthly testing. This demonstrates the effectiveness of providing redundancies to augment reliability, and the importance of regular gate testing to sustain 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 F2016. Some revisions have been delayed into early F2017 as a major update to the emergency plans is in progress.

An integrated communications plan for communities and First Nations downstream of the Campbell River System was implemented in F2015. The communications provide an understanding of the risks and assists in developing appropriate emergency action plans, following a major earthquake. The plan targeted general and specific communications across the province including Ministries, response agencies (e.g. EMBC), local municipalities, the general public, First Nations and residents of the City of Campbell River. A series of four public meetings were held, with about 40 public attendees at each meeting. Flood inundation mapping is now available via published brochures and the BC Hydro Dam Safety website. BC Hydro will continue to work with the response agencies and local municipalities to improve emergency response plans.

Operation, Maintenance and Surveillance (OMS) Manuals

All OMS manuals are reviewed and updated as necessary. In F2016, six of the eleven planned updates to OMS Manuals were completed, and the remaining five will be updated in early F2017.

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 F2016, Dam Safety Reviews were completed for Elsie, Buntzen, Falls River, Salmon River and Spillimacheen Dams.

The findings have been 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 February 9 and 10, 2016 to discuss matters of mutual interest.

F2016 Surveillance

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 monitor 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 issues addressed during F2016 are the following.

- *Seton Forebay Leakage*

Leakage from the Seton concrete forebay during unit cycling went from a historic 300 to 800 litres per minute to a peak of 3,000 litres per minute in April 2015. Rehabilitation work on the concrete panel joints was scheduled for July 2015, but environmental concerns delayed rehab work until April 2016. During this interim period, a ramping rate was imposed on the unit to limit forebay fluctuation surges. The forebay was dewatered in April 2016 and the inter-slab joints were re-caulked, bringing the leakage down to the 220 lpm range.

- *Buntzen Dam Spill Monitoring*

Buntzen Generating Station went out of service in March 2015, resulting in spill at the dam. Surveillance staff began daily spill monitoring for the local production staff until the unit could be brought back online a couple of weeks later.

- *Miscellaneous additional monitoring and instrumentation*

A satellite modem and radio was installed for a backup communications link for reservoir telemetry at Jordan Dam. Timing of the installation was fortuitous: the backup link was used in the fall for two weeks when the fibre optic communications line went down during a storm.

Additional real-time cameras were installed at Strathcona and Comox dams, oriented towards gated structures and spillways.

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 2016 – Capital Improvements

➢ *Duncan Dam – Instrumentation Improvements*

Sonic rig drilling standpipe piezometer

Pulling instrumentation cable

As part of the design and construction of Duncan Dam, a number of relief wells and piezometers were originally installed near the toe of the dam to control and monitor seepage. Over the intervening years, more than a third of these piezometers ceased to function or became inaccessible. The dam was under instrumented for its consequence classification in relation to modern monitoring expectations and other BC Hydro extreme consequence dams. In addition, the outlets for the relief wells and weirs are below tailwater during a portion of the year.

This project was initiated to install new instrumentation and connect instrumentation to the Automatic Data Acquisition System (ADAS). In F2015 instrumentation to monitor concrete cracking at the low-level outlet and surface drainage improvements at the left abutment was installed.

During F2016, the following work was carried out:

- twenty nine standpipe piezometers were installed in nineteen boreholes and instrumented;
- pumps were installed in five relief wells;
- instrumentation was connected to the Automatic Data Acquisition System;
- access manholes were installed on the downstream toe drain.

The instrumentation has been put in service and preparation of the construction report is in progress.

➢ *Wilsey Dam – Instrumentation and Access Upgrade*

Wilsey Dam-Access and Safety Improvement

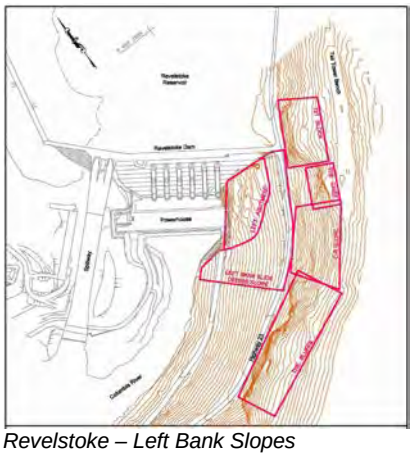
This project was initiated in F2016. The main project objectives were to:

- provide monitoring capability for existing drains in the foundation of the arch dam,
- re-establish piezometric monitoring capabilities in the left abutment, and
- establish safe access to the lower part of the dam for inspection purposes.

The construction works, including drilling and piezometer installations, drain upgrades, and access and safety improvements, were successfully completed in F2016. Key instruments are now connected to an Automatic Data Acquisition System. The completion of the construction documentation is in progress.

Pressure relief valve upgrade

North Conduit drain improvements



Revelstoke – Left Bank Slopes

Left Bank Slopes-Instrumentation Installation

➢ ***La Joie Dam – Water Passages Upgrades***

Following the failure of the pressure relief valve discharge at the South Conduit in February 2012, a reliable alternative water passage was required via the North water passage.

Work completed prior to F16 included:

- Replacement of the hollow cone valves in the North Conduit,
- Installation of a new low level outlet gate at the Intake Tower;
- Demolition of the damaged pressure relief valve conduit and construction of a new conduit,
- Upgrades to the pressure relief valve and section of the South Conduit,
- Design, fabrication and installation of new stoplogs, and
- Upgrades to the hollow cone valve heater systems.

Construction work in F2016 to provide North Conduit drain improvements have now completed the planned upgrades. Project documentation is in progress.

➢ ***Revelstoke Dam – Left Bank Instrumentation***

The Revelstoke left bank rock slopes potentially pose a hazard to the Revelstoke Penstocks and Powerhouse, situated immediately below. In F2013, an investigation study was initiated to determine the risk the slopes posed to the facility and to determine if any upgrades were required.

There are seven slopes of interest on the Left Bank of Revelstoke Dam. The study recommended further stabilization work for one slope, which will be carried out under a future project. However, the investigation also concluded that for another two slopes, the geology was poorly understood, and there was insufficient instrumentation to make a definite stability assessment. The investigation recommended that instrumentation be installed and additional geological information be collected to provide a technical basis for whether or not stabilization is required for these slopes.

This project was initiated in F2015 to gain a greater understanding of the stability through the installation of instrumentation. The following activities were included in the scope of work and were carried out in F2016:

- Rock slope scaling,
- Geological mapping,
- Access improvements,
- Drilling 7 holes and installation of piezometers, inclinometers, extensometers, and survey prisms,
- Surface safety improvements, and
- Studies to reduce uncertainty in geology.

The project construction documentation is in progress.

La Joie Dam – Interim Risk Management

La Joie Dam

Upstream Shotcrete Face of La Joie Dam

The existing shotcrete facing of La Joie Dam installed in 1972 has deteriorated, resulting in increased leakage through the dam. Some of the leakage is currently managed through maintenance of the shotcrete panels accessible during low reservoir periods. A previous study to understand the performance of the dam has concluded that the dam requires significant upgrades to ensure safe performance following the design earthquake.

Based on the dam safety priorities for the portfolio, the La Joie capital project to address these issues is now beyond the 10 year capital window. To address the risks in the interim until the capital project is completed, the feasibility assessment and ramification impacts of adopting a lower reservoir operating level was initiated in F2014. It concluded that reducing the maximum operating level of the reservoir is a viable alternative in reducing the dam safety risks.

An update to the La Joie Operation, Maintenance and Surveillance Manual was issued in F2015 in the form of an Interim Dam Safety Risk Management Plan. Repairs to the upstream face of the dam will continue to be carried out as required (annually or bi-annually).

Following the discussions with First Nations and the Comptroller of Water Rights and addressing a number of their concerns, the updated Interim Dam Safety Risk Management Plan was issued in January 2016, providing clarity on the need to reduce the reservoir to manage dam safety risk. The new lower normal maximum operating level was achieved in early February 2016.

Active Projects – Capital Improvements

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.

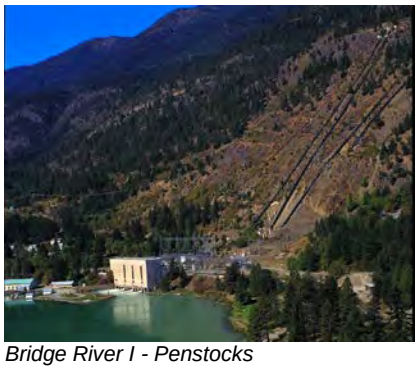
Ten sites were identified as requiring first tier priority work. The gate systems at 9 out of the 10 sites have been put in service in previous years. During F2016, construction continued at the outstanding site, Hugh Keenleyside.

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.

Hugh Keenleyside gates

➢ ***Hugh Keenleyside Dam***

Construction work is now substantially complete in F2016 at Hugh Keenleyside Dam 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.



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 penstocks 2 and 3 were completed prior to F2016. In F2016, installation of flowmeters on penstocks 1 and 4 was completed; alarm levels were set to detect significant leaks; and procedures for manual closure of the valves were included in the site operating orders.

Conceptual design of instrumentation to monitor for movements of the penstocks and powerhouse has also been completed.

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.

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

Comox Dam

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

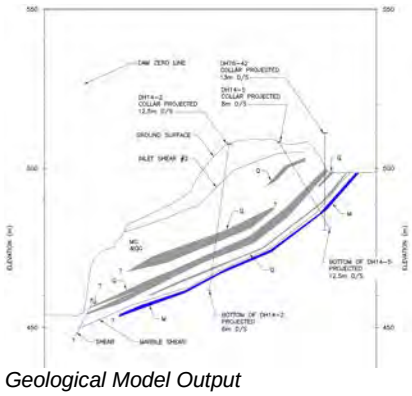
There are identified dam safety and public safety risks associated with the reliability of water conveyance at both Comox and Puntledge. These are primarily associated with the vulnerability of the public in Puntledge River due to spurious flow changes. Two inter-related capital projects were initiated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

➢ *Revelstoke Dam – Marble Shear Block*

Drilling in the Marble Shear Block



Geological Model Output

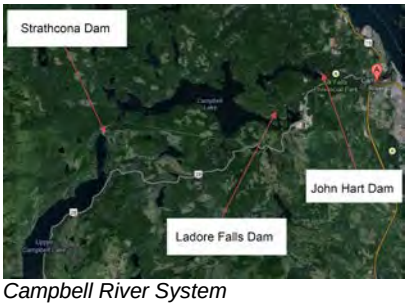
The Marble Shear Block is a large rock mass located on the right bank of the canyon at the Revelstoke Concrete Dam. At the time of construction, some movement of the block occurred during excavation for the dam and powerhouse. Extensive stabilization measures were implemented, and no significant movement 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, and that additional instrumentation to supplement the existing instrumentation would be beneficial in evaluating 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. This work will be carried out in F2017.



Campbell River System


Strathcona Dam

➢ ***Strathcona Dam– Low Level Outlet Seismic Upgrades***

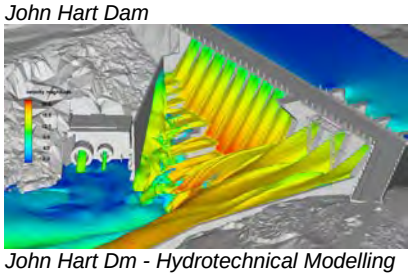
The seismic withstand of a number of Strathcona assets is currently insufficient. The construction of a new Low Level Outlet will provide a means to effectively lower the Upper Campbell Reservoir and protect the Strathcona Dam from failure and uncontrolled release of the reservoir in either a static or a post-seismic situation. As part of the new low level outlet design and construction, there is the opportunity to also allow for a new power intake tunnel to be used when the existing intake, water passage and power facilities are relocated. This future relocation will allow for future seismic upgrades to the Strathcona Dam itself.

This project was initiated in F2015. The first part of this project will determine feasible alternatives for the new Low Level Outlet, including the sizing of the new discharge and feasible 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 is included in this project to ensure that the layout will be compatible with the potential footprint for a future upgrade to the embankment dam.

The work started in F2016 includes:

- The assessment of the optimal invert elevations for the Low Level Outlet and target drawdown rates and discharges, and
- The assessment of the failure modes of the dam to determine the benefits of the Low Level Outlet.

John Hart Dam


John Hart Dm - Hydrotechnical Modelling

➢ ***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.

In F2016, work continued in developing conceptual upgrade options for the Middle and North Earthfill Dams, the Concrete Dam and the Intake Dam. A field investigations program was completed to obtain additional bedrock elevations and to obtain additional soil and rock samples.

The following activities were carried out in F2016:

- Advisory Board Meeting #1 was held to present the options for the Middle and North Earthfill dams, the Concrete Dam, and the Intake Dam.
- Additional analyses were carried out as part of the development of the Middle Earthfill Dam upgrade options, following the comments received from the Advisory Board;
- Hydrotechnical modelling was carried out for the existing spillway and the proposed passive spillway; and
- Conceptual design options were developed for the spillway gate systems.

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 held in Sooke. Liaison with the property owners continues, and a property purchase program is underway. One property was purchased in F2015. BC Hydro purchased seven residential parcels of land in F2016. The acquisition of the remaining properties, demolition of the buildings and land restoration is expected in F2017.

Ladore Dam

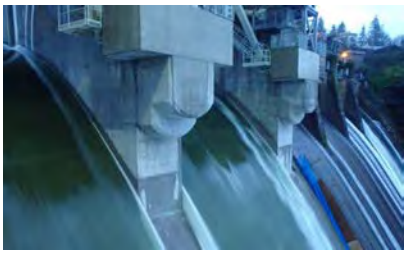
➢ ***Ladore Dam – Spillway Seismic Upgrade***

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. Post-seismic operability and reliability improvements will also be carried out. The conceptual design of upgrades was started in F2016

➢ ***Ruskin Dam and Powerhouse – Seismic Upgrades***

Construction of New Piers 4 and 5



Flow from new Spillway Gates No.1 and No. 2. Remaining old spillway gates can be seen in the background.

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.

Construction in F2016 included:

- Installation and commissioning of the first two spillway gates (Spillway Gates No. 1 and No. 2)
- Successful completion of the removal and transfer of the bulkhead to the new location, in front of old Gates 4 to 6
- Removal of existing Gates 4 to 6
- Removal of the existing Piers 4, 5 & 6
- Construction of new Piers 4 and 5, in progress
- Construction of the Left Abutment reverser filter berm and seepage flow measuring instruments; and
- Partial relining of critical sections in Tunnel 3.

Analyses of the overall dam performance are in progress. These analyses will determine the number and design of additional anchors required.

Salmon River Diversion Dam

➢ ***Salmon River – Refurbish Canal and Dam, Install Fish Passage***

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 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. In F2016, work completed includes:

- Final design of the upstream fish passage, with preparation for construction in spring/summer of 2016
- Design of the fish screen and dam/canal upgrades – in progress; and
- Updated total project cost estimates.

In late F2016, the forecast total project cost was estimated at $43M. Based on these increased project estimates and economic forecasts, a decision was made to review the decommissioning option, and the fish ladder construction was cancelled. Project re-scoping will be carried out in F2017.

WAC Bennett Dam Spillway Chute- Ice Flushing

WAC Bennett Dam Spillway Chute - Working Platform Construction

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

This project is carrying 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, and has previously completed:

- 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. 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 F2015. The plan is to complete the remainder of the upper portion and the entire lower portion of the chute in the 2nd year of construction. Due to the high risk of spill, a decision was made in late F2015 not to proceed with construction in 2015.

After monitoring the snow pack levels and generation operations in F2016, a decision was made in late F2016 to proceed with the 2nd construction season. The dam safety risks associated with being able use of the spillway, if needed, are addressed by the Interim Dam Safety Risk Management Plan. The Contractor mobilized to site in April 2016, and construction work is underway on the chute.

WAC Bennett Dam

Sand Flat Quarry-Access Road

➢ ***W.A.C. Bennett – Rip Rap***

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.

To provide design input, the need for site specific wind/wave data was identified, and a wind/wave buoy was re-deployed in Williston Reservoir in F2013 and again in F2014. This information was used in F2015 to further optimize the design of the new riprap. Additional field investigations were completed in F2015, and this information was used as input to the final design.

The work completed in F2016 includes:

- Completion of the final design of the riprap;
- Updated cost estimates;
- Preparation and submission of the documents to the BC Utility Commission, and responses to the Information Requests;
- Development of draft procurement strategies for the construction
- Preparation of contract documents, tendering of the contract and awarding the riprap construction contract.

Full project funding approval and start of borrow development are expected in early F2017.

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Evaluating sealing/grouting techniques

➢ ***W.A.C. Bennett – Core Upgrade***

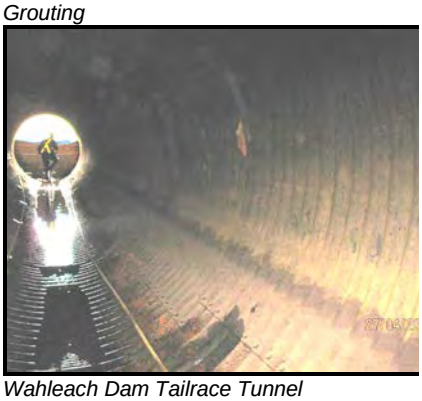
A number of open casings (observation wells, drillholes and cross-arm device) were installed in the core of the dam during construction and later, during sinkhole remediation. The water levels in some of the casings (the observation wells) have been observed to fluctuate and to suddenly drop indicating 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 measurements, if possible.

In F2016, all six observation wells and the four out of the five selected drill hole casings were successfully grouted. The design work to address the remaining drill holes in the dam core was also carried out in F2016. A request for proposal for investigating the options for unblocking the Cross-Arm device was issued.

W.A.C. Bennett-Observation Wells Grouting



Wahleach Dam Tailrace Tunnel

➢ *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. An inspection of the tailrace tunnel is planned for April 2016. This information will be used to develop relining designs n F2017.

Duncan Dam- Prepartion of the site prior to installation of the sheet-piles

Duncan Dam- Prepartion of the site prior to installation of the sheet-piles

➢ *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. Consequently, 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 2016), if possible. The objective is 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 top of the sheet-pile wall will be constructed to a height of the original designed top of the core, about 7 to 10 ft higher than the present core. To assist in the design, a series of test pits were completed in February 2016. The designs were completed and contracts were awarded by March 2016. The start of construction is planned for April with completion targeted for July 2016.

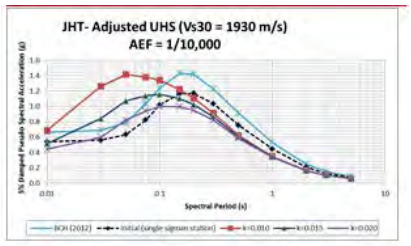
Alouette Dam and Intake Tower

➢ *Alouette Dam- Intake Structures 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 desired project outcome is a power tunnel/adit tunnel that can be relied on to pass the Alouette Lake inflows to Stave Lake post maximum design earthquake. This project was initiated in F2016, with the preparation of the plan for identify and develop conceptual options. Work will start in F2017.



➢ ***System-Wide – 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 and project documentation is planned for F2017.

Projects Completed in Fiscal 2016 – Performance Investigations

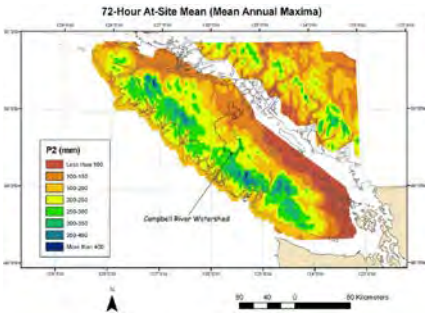
Campbell River System - Dams

➢ ***Campbell River System – Evaluation of Increased Flood Passage Capability and Strathcona Spillway Modelling***

The current flood passage capability of this river system is in the order of 76% of the Probable Maximum Flood (PMF). In view of the upcoming dam upgrades, a study was initiated in F2014 to investigate potential upgrades which could further increase the flood withstand without major site reconfiguration.

The Computational Fluid Dynamics modelling of spillway flows for higher reservoir elevations and project documentation were completed in F2016.

Increased flood passage capability is best achieved through increased storage at Strathcona; by spilling modifications, and/or by increasing the dam height. These options will be considered as part of the future Strathcona Spillway seismic upgrade project.

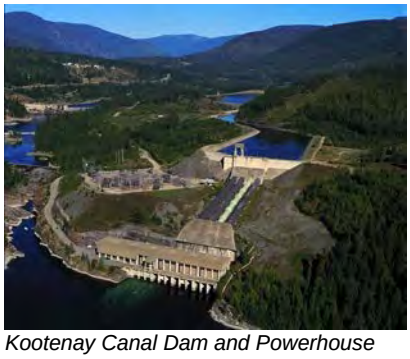


Campbell River - Precipitation

➢ *Campbell River System – Flood Estimations*

This investigation was initiated to carry out an evaluation of the uncertainty around the probability estimates of reservoir levels in floods. In F2015 one of the existing methods for flood evaluation was re-formulated to provide reservoir level probabilities rather than just inflows. The analyses included uncertainty estimates and various gate unavailability scenarios.

The hydrotechnical modelling and documentations were completed in F2016. The outcome document describes the probabilities for reaching various reservoir levels under various flood conditions and suggests various dam safety strategies regarding the flood hazard withstand.



Kootenay Canal Dam and Powerhouse

➢ *Kootenay Canal – Seismic Stability*

This investigation is assessing the seismic performance of the canal and appurtenant structures*.* Sensitivity analyses on the stability of the power intake and gravity blocks were carried out in F2014. In F2015 evaluation of the concrete-rock interface strength was completed and the sensitivity analyses updated. This project was completed in F2016, by assessing the seismic performance of the headworks structures, the power intake, and the gravity blocks. Instrumentation upgrades will be undertaken in the future to provide a more representative assessment of the seismic performance of the concrete structures at Kootenay Canal facility.

Terzaghi Dam

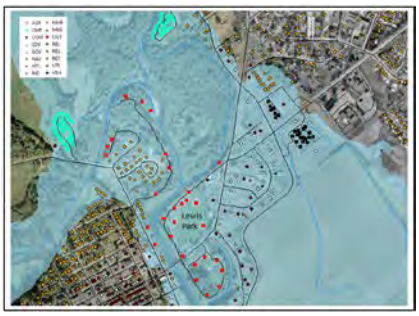
Terzaghi Dam- Spillway and low level outlet tunnel

➢ *Terzaghi Dam – Seismic Performance*

Terzaghi earth-fill dam, 60 m high, is located about 50 kilometers upstream of the town of Lillooet. It is the second of the three dams on the Bridge River system, with La Joie Dam situated 56 kilometers upstream. The seismic stability of the dam was first evaluated between 1987 and 1995. An investigation was initiated in F2014 to assess the seismic performance of the dam and appurtenant structures for the 2012 seismic hazard results. The first phase of the seismic assessment was completed in F2015 and included assessments of:

- the embankment dam and foundation;
- the spillway retaining the reservoir and dam core; and
- the low-level outlet.

The second phase analyses were completed in F2016. The investigation concluded that the dam will be damaged in the Maximum Design Earthquake; however a release of the reservoir will not occur. The low level outlet could also become blocked as the toe of the dam deforms. Relatively simple upgrades were recommended to mitigate this particular issue, as the ability to drawdown the reservoir in a post-seismic situation needs to be ensured, and these upgrades will be undertaken in a project to be entered into the capital plan.



Puntledge Inundation

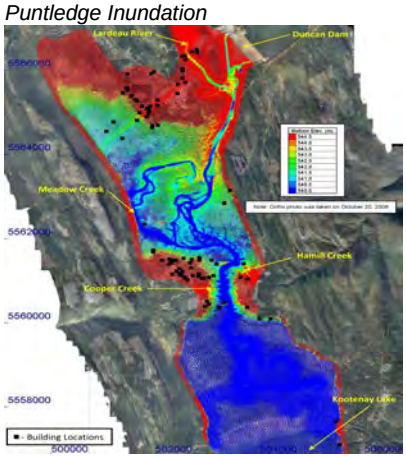
➢ ***Life Safety Model- Puntledge Inundation***

The Life Safety Model is a computer simulation software, originally developed by BC Hydro, that can be used to assess the interaction of people and buildings at risk below dams to various flood hazards.

In F2013, a project was initiated to carry out a Life Safety Model of the Campbell River system. The Campbell River system includes Strathcona, Ladore and John Hart Dams. The Life Safety Model is a useful tool that can help guide the development and testing of emergency response plans.

Additional work on the development of a model for the Puntledge River system was completed in F2016. The report identified the potential vulnerable areas downstream of the dam and the means to reduce the flood hazard impacts. It was concluded the vulnerable population is mostly comprised of transient people such as occupants of parks and campgrounds. This result will be used in the development of an overall approach to provide better public awareness of risks along the Comox-Puntledge waterway.

Puntledge Inundation



Duncan Dam-Downstream Inundation Model

➢ ***Duncan Dam-Downstream Inundation Assessment***

As noted above, recent work has shown that the uppermost portion of the core will not act as an effective water barrier, and surcharging of the reservoir is currently not allowed. The inability to surcharge will increase the likelihood of downstream flooding during freshet water management.

This investigation assessed the potential downstream flooding impacts assuming that surcharge above the full pool remains unavailable. The studies indicated that downstream inundation could be significant, even for a flood event with a return period as low as 20 years. Very little warning time would be available to downstream residents, and a population at risk (PAR) estimate of 47 was determined for the 20-yr flood. Therefore, the capital project as previously described was initiated on an urgent basis in January 2016 to address this issue.

Active Projects – Performance Investigations

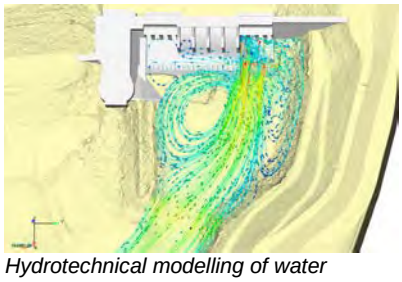
Coquitlam Dam

➢ ***Coquitlam Dam Data Compilation***

This investigation was initiated in F2016 and involves compilation of the data and information on the design of the new Coquitlam Dam. Most of the tasks were completed in F2016.

The completion of a 3-D model of the entire dam, including the original earthfill dam will be carried out in F2017.


Hugh Keenleyside Low-Level Outlets (right side of photo)


Hydrotechnical modelling of water discharge from the Low-Level Outlets

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

Since operations began at Hugh Keenleyside Dam in 1968, there has been concrete erosion occurring at the Low-Level Outlets, which 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 to determine inspection and concrete repair methodologies, and to develop an operational discharge sequence such that the dam can be operated sustainably, both structurally and environmentally into the future.

Work carried out in F2016 consisted of:

- Completion of investigation into underwater concrete repair methodologies;
- Preparation of environmental monitoring approaches and analyses to investigate the environmental impacts of increased discharges through the spillway and Low-Level Outlets.
- Theoretical modelling of the environmental impacts of water discharge,
- Identification of suitable underwater surveying methodologies;
- Completion of a three dimensional model of Hugh Keenleyside Dam structures and its downstream riverbed,
- Preliminary hydrotechnical modelling of water discharge from the Low-Level Outlets and spillways,

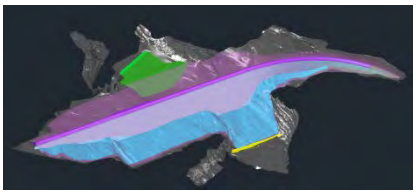
Selection of the vendor and awarding the contract to conduct underwater survey of the Low-Level Outlets No 1-4 (north ports). The underwater survey will be carried out in early May 2016.

➢ *Ladore Dam – Seismic Stability*

Ladore Dam

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. Additional analyses were carried out in F2016 and preparation of a summary report is in progress.



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. 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 in three meetings. The panel report was issued in August 2012.

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.

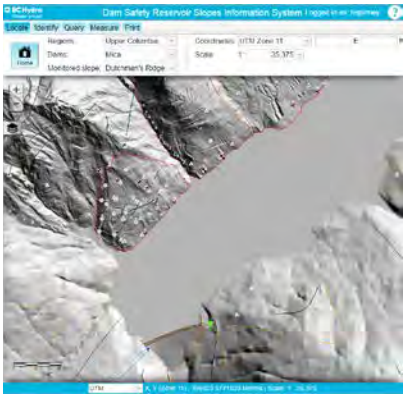
The Expert Engineering Panel was reconvened in F2016 to review the results from the past 3 years of work by BC Hydro. It stated in their 2nd report *that the work undertaken by BC Hydro over the past 3 years confirms their 2012 conclusions on the satisfactory condition of the dam, and that the filtering 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.

Active Projects – Initiatives

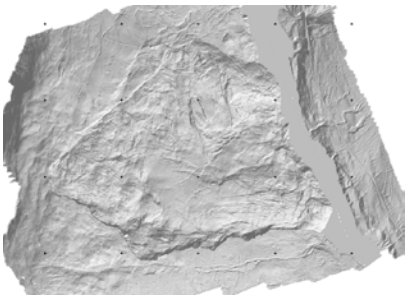


- ***GIS Information Management***

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 is expected to start mid F17 to expand the system to include dams and access to other BC Hydro information systems

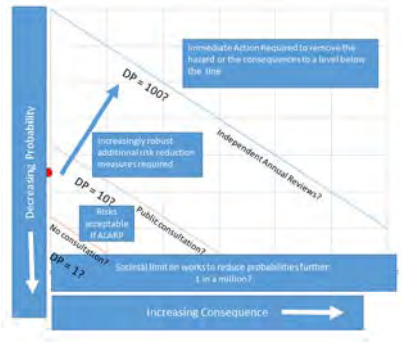


LiDAR image Downie Slide

- ***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 F16 did not allow a comparative analysis. This has led to a scrutiny of data collection methodology to ensure future work is successful.



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.

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. In F2013, the liability associated with these water licences was reviewed by BC Hydro's Legal Services. Work remains to determine appropriate actions to address BC Hydro's liability in one particular case; Croil Lake. This initiative will be restarted in F2017 with reference to the new BC Dam Safety Regulation which provides some clarity on dam ownership.

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)*

	F2016 Plan	*F2016 Actual*
Performance Investigations	2.80	2.68
Surveillance	3.99	4.03
Regulatory, Risk, Other Program Activities and Administration	2.68	2.71
New Interim Risk Management Initiatives (Vancouver Island seismic resilience and Downton Reservoir reduced maximum operating level – see next section)	0	0.36
Departmental budget	9.47	9.78
Capital improvements[1,2]	186.56	148.79

Notes

1. *Capital improvements cover dam safety initiated projects and the dam safety portion of the Ruskin Dam and powerhouse upgrade project for F2016.*
2. *Underspend this past year was mainly due to deferrals:*
    a. *Salmon River-Refurbish Dam & Canal: deferred by one year in order to complete necessary consultations and planning.*
    b. *WAC Bennett-Spillway Chute: the 2nd year of construction was deferred due to forecast of high risk of spill in F16.*
    c. *WAC Bennett-Rip Rap: Forest Service Road upgrades deferred from F16 to the main contract in F17.*
    d. *Generally longer planning periods for Spillway Gates Upgrade projects at WAC Bennett and Peace Canyon*
    e. *Bridge River I - Penstock Leak Detection: implementation of Geotechnical Instrumentation was deferred to complete detailed scoping and design.*

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. Methods have now been developed to incorporate the results of the Probabilistic Seismic Hazard Analysis project into the damage assessments that have been previously undertaken for the Transmission system. 'Proof of concept' for these methods is underway. Once confirmed, the damage assessment work for the key Transmission assets that was previously undertaken will be re-run with this new input. This first stage work will allow for a direct comparison of results. Following this, the model will be expanded to include Generation and some key Distribution assets. Later stages will use these results to develop proactive and reactive plans for sytem recovery following a major seismic event.

- ***Downton Reservoir Reduced Reservoir Level***

A requirement has been put in place to operate the Downton Reservoir to a lowered reservoir elevation of 734.0 m, to be in effect until the La Joie dam undergoes major upgrades. It was expected that this could be achieved without exceeding the Bridge Water Use Plan target hydrographs for Terzaghi under normal inflow conditions. However, due to significant forced outages, recent equipment de-rates and high inflows over past 2 years, it was not possible to achieve 734.0 m without exceeding the Lower Bridge River Water Use Plan target hydrographs in 2016 and is expected to create additional challenges for water management for Lower Bridge River under the near term capital and maintenance plans. This initiative has been funding the necessary engineering work and consultations with First Nations and stakeholders, as a longer-term approach to this issue is developed.

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 is nearing completion. The text of the forthcoming book *Operational Safety of Dams and Reservoirs* that reflects the results of this collaboration was submitted to the publisher It is expected that the book will be published during 2016/17.

BC Hydro's continuing contribution is 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 preparation of a Technical Bulletin on Dam Safety Reviews 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. BC Hydro is also a contributor to the work of the Committee on Floods. The ongoing work to develop guidance on Dam Safety Management in all phases prior to Operation and the Seismic design work representing internationally-accepted practice, are both progressing as planned. The Committee on Dam Safety has two other working groups on Risk Assessment and Dam Failure Consequence Assessment. These 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. Currently, work addressing dam safety needs is 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.

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	7	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)		
Seismic Upgrades	Mr. D. Johnston (USA)		
	Dr. Y. Ghanatt (USA)	1	August/September 2015
	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
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	1	September 2001
	(External Reviewer)	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	Dr. K. Hoeg, Norway	1	March 2011
	Mr. R. Bridle, UK	2	July 2011
	Dr. R Fell, Australia	3	February 2012
BC Hydro System			
Gate reliability upgrades	Dr. Geoff M. Ballard, New Zealand	Ongoing advice	2007 - present

Appendix C:
Projects

Table 1: Dam Safety Improvement Projects

$ Thousands

		Actuals (Current Year)	Total Actuals (To Date)
Active			
General Capital			
Allouette	Seismic Upgrade	39	39
Bridge River I	Penstock Leak Detection and Protection	1,635	5,365
Bridge River I	Slope Drainage Improvement	607	607
Comox- Puntledge	Flow Control Improvements	403	1,035
Duncan	Core Cutoff Wall Installation	104	104
Duncan	Instrumentation Improvements	3,204	5,206
John Hart	Seismic Upgrade	2,534	5,007
Jordan	Mitigate Seismic Risk	4,491	5,540
Ladore	Spillway Upgrade	293	397
Revelstoke	Marble Shear Block	144	1,373
Ruskin	Seismic Upgrade	103,814	423,178
Salmon River	Refurbish Dam & Canal	1,714	2,691
Strathcona	Low Level Outlet	451	485
WAC Bennett	Spillway Chute	915	11,387
WAC Bennett	Core Upgrade	1,462	2,435
WAC Bennett	Rip Rap	2,984	10,179
Wahleach	Intake/Penstock Upgrade	10	10
Wahleach	Tailrace Replacement	40	40
Various Sites	Debris Booms	1,130	1,183
Various Sites	Rock Correction for Seismic Hazard	611	1,086
Spillway Gates			
Clowhom	Spillway Gates & Diesel Generator	64	101
Peace Canyon	Spillway Gates Upgrade	771	3,066
Strathcona	Spillway Gates Upgrade	20	20
Sugar Dam	Spillway Gates Upgrade	53	117
WAC Bennett	Spillway Gates Upgrade	1,719	5,384
	TOTAL	**129,212**	**486,035**
In-Service/Completed/Closed			
General Capital			
Kootenay Canal	South Forebay Leakage	21	8,588
La Joie	Water Passages Upgrades	535	10,378

La Joie	Interim Risk Management	2	4,203
Mica	Instrumentation Upgrades	293	11,149
Revelstoke	Left Bank Instrumentation	1,300	1,630
Ruskin	Right Abutment	2	16,321
Stave Falls	Flood Protection Upgrade	1	44
Wilsey	Instrumentation Improvements	700	706
Spillway Gates			
Hugh Keenleyside	Spillway Gates Upgrade	15,940	107,630
Cheakamus	Spillway Gates Upgrade	41	63,770
Duncan	Spillway Gates Upgrade	75	30,916
Seton	Spillway Gates Upgrade	115	21,962
Stave Falls	Spillway Gates Upgrade	441	50,585
Terzaghi	Spillway Gates Upgrade	106	38,680
	TOTAL	**19,572**	**366,561**
	TOTAL (Active, In-Service/Completed/Closed)	**148,784**	**852,596**

Table 2: Performance Investigations

		$ Thousands	
		Actuals (Current Year)	Total Actuals (To Date)
Active			
System wide	Seismic Hazard - Target Spectra and Time History Guidelines	244	244
System wide	GIS Information Management	57.9	162.7
System wide	Remote Sensing for Landslide Detection	38.9	255.7
System wide	Tolerability of Risk	197.5	317.3
System wide	Dam Special Investigations (WAC Bennett Embankment Dam)	1,136.5	3,089.3
System wide	Reservoir Level Monitoring and Gates Heating	89	130.9
Coquitlam	Data Compilation	88.4	88.4
Hugh Keenleyside	Low Level Outlet Operations	125.6	315.5
Ladore	Seismic Stability	40.3	463.4
Peace Canyon	Seismic Stability	3.7	208.6
	TOTAL	**2,021.8**	**5,275.8**
Completed			
System wide	Probabilistic Flood Hazard Analyses (CBL Flood Estimations)	42.6	961.3
System wide	Life Safety Model	19.2	384.6
Bridge River 1	Penstock Slope Runoff Monitoring	1.3	26.9
Campbell River System	System Requirements and SCA Spillway Modelling	37.3	136.2
Campbell River System	Evaluation of Increased Flood Passage Capability	19.8	84.1
Duncan	Downstream Inundation Analysis	24.8	24.8
Kootenay Canal	Seismic Stability	13.4	1,097.7
Terzaghi	Seismic Stability	465.5	1,195.6
WAC Bennett	Low Level Outlet- Long term Options	36.8	67.4
	TOTAL	**660.7**	**3,978.6**
	TOTAL (Active and Completed)	**2,682.5**	**9,254.4**