

MANAGEMENT AUDIT REPORT

GENERATION BUSINESS GROUP

DAM SAFETY AUDIT Q3 F2014

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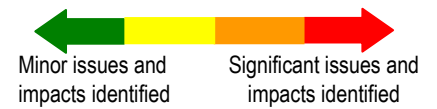
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Legend:



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1a. Executive Summary

- ❑ For each audit, Audit Services provides two separate Audit Reports. The first report is a Summary Audit Report prepared for Senior Management and the Audit & Finance Committee (AFC) of the Board. This Management Audit Report provides additional information and related audit recommendations for management purposes and will not be presented to the AFC.
- ❑ Management should also refer to the Summary Audit Report for high level conclusions and findings.

1b. Background

- ❑ BC Hydro has more than 80 dams and reservoirs at over 40 sites ranging in age from 5-110 years and in size from minor structures to some of the largest dams/reservoirs in the world.
 - ❑ BC Hydro has an ongoing Dam Safety Program that ensures dams are inspected regularly and safety is enhanced to meet international best practices and regulatory requirements.
 - ◆ Dam owners in British Columbia are expected to comply with Provincial Regulations and follow guidelines set by the Canadian Dam Association (CDA) and the International Commission on Large Dams (ICOLD).
 - ❑ The Dam Safety Program average costs from F2010 to F2013 have been fairly stable at approximately \$115M per year, with approximately 86% being spent on capital improvements. The key elements of the Dam Safety Program include:
 - ◆ Surveillance – early detection, visual checks/measurements and Dam Safety reviews.
 - ◆ Risk management – risk assessment methodology, capital prioritization and decision support.
 - ◆ Performance Investigations – engineering studies, options and technical reviews.
 - ◆ Capital Projects – project delivery, remediation, mitigation and risk reduction.
 - ◆ Operations – civil maintenance, and infrastructure such as spillway gates and penstocks.
 - ◆ Emergency Preparedness – response plans, downstream communities and environmental impact.
 - ◆ Public Safety – all safety measures around or near dam sites.
 - ❑ The Director of Dam Safety, who resides in Generation Dam Safety, oversees the Dam Safety Program and works alongside other Generation groups (Project Delivery, Operations, and Operational Safety) and the T&D Emergency Management group to manage and implement the Dam Safety Program.
 - ❑ Audit Services conducts an independent audit of the Dam Safety Program every 5 years due to the very high consequence of dams failing. The previous audit was conducted in Fiscal 2009. The audit reviews the management framework and is an integral part of the Dam Safety Assurance function.
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1c. Audit Objective and Scope

Objective

- To evaluate whether Dam Safety risks are properly identified, prioritized, and managed to ensure achievement of Dam Safety objectives.

Scope

- Review key elements of BC Hydro's Dam Safety Management System which included:
 - ◆ Governance structure
 - ◆ Regulatory & Compliance
 - ◆ Risk assessment
 - ◆ Dam Safety Program Implementation including surveillance, civil maintenance of critical structures, performance investigations and capital projects, and emergency management.
- The audit team was supplemented by two international Dam Safety subject matter experts.
 - ◆ Dr. Georges Darbre (Regulator's perspective) -Commissioner for Dam Safety at the Swiss Federal Office of Energy, Bern, Switzerland. Member of the Advisory Committee of the Dept. of Civil Engineering at the Swiss Federal Institute of Technology in Lausanne and member of the Swiss Committee on Dams.
 - ◆ Mr. Norman Himsley (Dam Owner/Operator's perspective) -Chairman, New South Wales Dam Safety Committee's Surveillance Sub-Committee. Chairman of Australian National Committee of Large Dam's Professional Development Working Group. Practicing consultant specialising in Dam Safety management with over thirty-five years of extensive experience.

1d. Findings, Recommendations and Management Action Plans

Summary

BC Hydro continues to have a strong Dam Safety Program which includes an effective governance model and a robust risk assessment process consistent with international best practices. Key Dam Safety Program activities are being well executed with some areas for improvement.

Governance

Overall Conclusion

Effective governance over the Dam Safety Program is in place including several positive changes implemented since the last audit in F2009. Succession planning for key roles is still at its early stages.

Key Conclusions and Findings

- An improved governance structure is in place compared to five years ago and a formal BC Hydro Statement on Dam Safety is now in place and is being referenced in the Corporate Safety Policy.
 - ◆ The Director of Dam Safety reports to the Executive Vice-President Generation, as well as to the Capital Projects Committee of the Board ("Board"). Previously, the Director of Dam Safety

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had a dual role as Chief Officer of the Safety, Health and Environmental group, and reported directly to the Chief Executive Officer and to the Board.

- ◆ Feedback from various business groups involved in Dam Safety confirm that roles and responsibilities are clearly defined and communicated across BC Hydro.
- Appropriate Board and Management oversight is in place to support Dam Safety objectives. Currently, experienced and technically skilled individuals occupy the Board and Director of Dam Safety positions.
 - ◆ The Director of Dam Safety provides quarterly Dam Safety reports to a designated Board Director who is a seasoned civil engineer and understands the technical aspects of Dam Safety risks. In addition, he provides weekly updates to the Executive Vice President, Generation.
 - ◆ The Dam Safety Group is now an active participant of the Generation Management Team meeting alongside with Resource Management, Project Delivery, Engineering and Asset Management, who are all key partners in managing Dam Safety at BC Hydro.
- Succession planning to maintain appropriate competence for key Dam Safety personnel is still at its early stages. This is critical to ensure Dam Safety systems can recover from key personnel changes.
 - ◆ Key positions requiring succession planning include the Director of Dam Safety, Dam Safety Initiatives Manager, Surveillance Manager, and Dam Safety Engineers in general.
 - ◆ BC Hydro should ensure that the future designated Board director(s) overseeing Dam Safety continue to have the necessary technical experience.

	Recommendations	Management Action Plans
	Governance	
1	□ Develop a succession plan for key positions in the Dam Safety Group, including: fostering a structured professional development program to maintain and enhance competency levels.	□ Management will prepare a succession plan and foster professional development for key positions in the Dam Safety Group by March 31 2014.

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Regulatory & Compliance

Overall Conclusion

BC Hydro is in compliance with BC Provincial Dam Safety Regulations. Audit testing indicated that BC Hydro complies with the Dam Safety Program Implementation Manual and the Operations, Maintenance and Surveillance (“OMS”) Manuals with some minor exceptions noted.

Key Conclusions and Findings

Regulatory Relationship

- ❑ The Comptroller of Water Rights (the Regulator) confirms that BC Hydro is in compliance and commends the organization’s transparent and forthcoming communication culture. It is important for BC Hydro to continue proactively communicating any non-conformances through the Annual Compliance Report.
- ❑ The Regulator’s biggest concern is BC Hydro’s high risk profile, however, our interview with the Regulator indicated that they are satisfied with the prioritized upgrading program and the overall risk reduction rate.
 - ◆ There is also support for BC Hydro’s move from a standards-based to risk-informed decision making process in line with the Canadian Dam Association (CDA) guidelines.
- ❑ BC Hydro actively incorporates national and international good practices in managing its Dam Safety Program. As the Provincial Regulations are not overly prescriptive, BC Hydro adequately refers to CDA guidelines and international best practices, as well as actively contributes to best practices development such as the CDA and the International Commission on Large Dams.

Operations Maintenance Surveillance Manuals (OMS)

- ❑ The Regulator indicated that BC Hydro’s OMS Manuals consist of robust, detailed documentation of operations, maintenance and surveillance procedures and practices. They noted BC Hydro is slightly behind in updating their manuals but were not overly concerned.
 - ◆ The Provincial Dam Safety Regulations require dam owners to review and revise the OMS manuals, if necessary, every seven years for extreme classification dams and every ten years for very high and significant classification dams.
- ❑ BC Hydro has initiated a project to update the OMS manuals but are behind schedule completing two of 14 manuals planned for updating in F2014. With the addition of a new resource, Management indicates they plan to complete the remaining manuals in the coming months.
- ❑ Audit Services tested two facilities and the majority of OMS requirements were met. Minor exceptions included flow control structure testing, high pressure cleaning of drains and condition assessment of water passages. The Subject Matter Experts confirm that these are minor issues.
 - ◆ The gate testing program is well developed but while the flow mechanism inventory has been recently completed, further work is required to determine inspection methods, scheduling, condition status and prioritized rectification of these flow mechanisms.

Dam Safety Program Implementation Manual

- ❑ Audit Services selected eleven sections from the Dam Safety Program Implementation Manual (version June 2013) to test for compliance. Seven of 11 sections tested are in full compliance. Exceptions related to the four remaining sections are as noted below:

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- ◆ Training records are not kept centrally relating to surveillance training courses provided by the Dam Safety Engineers to the Plant staff across the regions.
- ◆ Not all dam sites are inspected weekly or monthly as per Program Implementation Manual. In 2012, 1 of fourteen dams requiring monthly inspections have missed three or more inspections. Five of 26 dams requiring weekly inspections have missed five or more inspections.
 - Management indicated that this is due to a number of reasons, including weather and access restrictions, and manpower constraints.
- ◆ Not all instrumentation are calibrated as per manufacturer's instructions due to time constraints and the costs outweighing the benefits (not practical).
- ◆ The Quality Assurance program on surveillance reporting and related results are not fully developed as the current program is heavily focused on the review of surveillance data.

	Recommendations	Management Action Plans
	Regulatory & Compliance	
2	<input type="checkbox"/> Refer to recommendation #5 in the Surveillance Section that addresses the findings relating to compliance testing.	<input type="checkbox"/> NA

Risk Assessment

Overall Conclusion

BC Hydro has a formal and robust risk assessment methodology in place to identify, prioritize and evaluate Dam Safety risks, and the methodology is in line with international Dam Safety practices. Opportunities for improvement exist in the Vulnerability Index ranking process.

Key Conclusions and Findings

Risk Methodology Process

- The risk methodology appropriately identifies and tracks Dam Safety risks in a robust, transparent and systematic way in line with international risk management practices.
 - ◆ All new deficiencies and non-conformances identified through surveillance activities, performance investigations or other means are entered in the Dam Safety Database for follow-up until they are resolved.
 - ◆ Dam Safety deficiencies and potential deficiencies are characterized and rated in terms of Vulnerability Index (VI), for the purpose of prioritizing risk reduction projects.

Dam Safety Issues Database

- The Dam Safety Issues Database is central to BC Hydro's risk assessment process and provides a comprehensive repository of all Dam Safety issues. The database is reviewed and updated on a quarterly basis. However;

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- ◆ There are several other databases and documents containing Dam Safety issues which are not directly integrated into the Dam Safety Issues Database. They include Passport, civil maintenance spreadsheet, or issues documented in surveillance reports.
- ◆ The access management and issues closure processes within the Dam Safety Issues Database are not formalized.
 - Some Dam Safety personnel are confused what reports are required prior to reducing the VI or marking an issue as “complete” in the Dam Safety Issues Database.

Vulnerability Index (VI)

- The VI provides a relative measure of the gap magnitude between performance capability and normal expectation of the dam feature, under best Dam Safety practices. However, some limitations exist in the VI rating process such as:
 - ◆ VI inputs may not be rated consistently depending on the initiator of the input and their level of understanding of the process.
 - ◆ System deficiencies (operational, procedural, management) are not included in the VI assessment process.
 - ◆ The VI is quantified based on the sum of individual deficiencies at a dam and not on an overall dam basis, which may lead to over estimation of the overall dam vulnerability.

Capital Projects Prioritization Process

- A formal process is in place to rank and prioritize capital projects across BC Hydro with significant influence from the Dam Safety Group.
 - ◆ The Asset Management group has developed an enterprise risk prioritization methodology and now has a capital investment guide to prioritize all capital projects across BC Hydro. Dam Safety risks are ranked very high and related capital projects are being addressed with the highest priority.

	Recommendations	Management Action Plans
	Risk Assessment	
3	<ul style="list-style-type: none"> □ Formalize processes to ensure: <ul style="list-style-type: none"> ◆ All dam issues are integrated into the Dam Safety Issues Database. ◆ Access management and issues closure procedures within the Dam Safety Issues Database are clear, such as identifying the proper closing reports prior to marking an issue as “complete”. 	<ul style="list-style-type: none"> □ The Director of Dam Safety will develop and formalize the Dam Safety issues integration process in the Implementation Manual by December 31, 2014. □ The Director of Dam Safety will clarify the access management and closure procedures in the Implementation manual by December 31, 2014.
4	<ul style="list-style-type: none"> □ Address the current limitations in the VI rating process: <ul style="list-style-type: none"> ◆ Communicate the VI rating and prioritization procedures to the Dam Safety Group to maximize “ownership” across BC Hydro of the risk assessment 	<ul style="list-style-type: none"> □ The Director of Dam Safety will address the VI limitations as follows: <ul style="list-style-type: none"> ◆ In 2014, more workshops on VI will be held across the group, with specific emphasis on working through examples.

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	Recommendations	Management Action Plans
	<p>processes.</p> <ul style="list-style-type: none"> ◆ Consider areas relating to system (operational, procedural, management) deficiencies in the dams risk assessment. This process has begun within the spillway gates investigation program and should be progressively implemented across all BC Hydro risk assessments. 	<ul style="list-style-type: none"> ◆ The Principal Engineering Scientist will be assigned to augment the VI system to include system deficiencies considerations by December 31, 2014.

Dam Safety Program Implementation

Overall Conclusion

Overall, key Dam Safety Program activities are being well executed, with improvement opportunities in surveillance, civil maintenance and emergency management.

Key Conclusions and Findings

Surveillance

- BC Hydro has a comprehensive surveillance management program in place in line with international practices with opportunities for improvement.
 - ◆ BC Hydro surveillance program combines frequent visual inspections by plant staff or technologists, data monitoring, regular site inspections as well as Dam Safety reviews by the Dam Safety Engineers.
 - ◆ The Dam Safety personnel at all levels are motivated and competent; which is central to a successful dam surveillance program.
 - ◆ Annual or semi-annual surveillance inspections and reports were completed for all dams for F2010 to F2013 per regulatory requirements. Frequency of formal inspections (annual or semi-annual) is done based on consequence category of each dam.
- In F2013, the BC Hydro seismic hazard model was completed to compute seismic ground motions at any site in BC. The model has been used to update the seismic hazards at all BC Hydro dam sites.
- While all elements of a comprehensive surveillance program are in place, several minor deficiencies have been identified primarily due to the lack of a surveillance self-assessment process. These deficiencies include:
 - ◆ A Quality Assurance program is not formalized and is focused on measurement data only. Findings from surveillance inspections are not formally cross-referenced between dam sites to enhance knowledge sharing.
 - Management advise a full-time seasoned Dam Safety Specialist Engineer is now on board to formalize and to expand the Quality Assurance Program.

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- ◆ Test operation of outlet facilities is performed according to the specifications of the OMS manuals with the exceptions of Wahleach Dam and Terzaghi Dam, where testing is not done due to the lack of proper maintenance instructions.
- ◆ The depth of interaction between the Dam Safety Engineers (DSEs) and the plant managers varies from one region to the other, ranging from daily visits to annual visit in certain sites.
- ◆ The DSEs have few opportunities to exchange and interact face-to-face to foster continuing professional development. This is also important to facilitate the current transition from “experienced-based” to performance-based surveillance.

Civil Maintenance (CM)

- While the CM Program has been strengthened since the F2009 Dam Safety Audit, the process to prioritize and resolve the current backlog of CM work is informal, and a formal civil preventative maintenance strategy is not yet in place.
 - ◆ A dedicated annual budget of \$3-4M has been set aside for the CM Program with a full-time person assigned to manage the CM work across BC Hydro.
 - ◆ The Dam Safety Group with input from the Asset Management group determines the allocation and assignment of CM work.
 - ◆ A spreadsheet is now in place to document all outstanding CM work to be completed in the next five years with the work prioritized through an informal process. The five years of work represent the current backlog and does not reflect any CM work that may arise in the future.
- While a central system is used to record, prioritize and manage mechanical and electrical preventative maintenance, a similar system is not yet in place for CM. The CM spreadsheet is a product of the CM Manager reviewing the Passport application, the Dam Safety Issues Database and various reports such as the annual compliance report at a point in time.
- Currently there is a significant gap between the CM work proposed to be done in a fiscal year versus what work can be done within the \$3-4M annual budget. Planned CM work is budgeted at \$6.2M to \$12.4M from F2015 to F2018 based on estimates provided by the Dam Safety Group.
- Deficiencies related to monitoring of reservoir levels are addressed in priority sequence. However the Subject Matter Experts indicate some of the deficiencies can be fixed easily in certain locations (Elsie, Clayton Falls, Buntzen, Falls River) irrespective of the dams’ consequence category.

Performance Investigations and Project Delivery Process

- Dam Safety performance investigations and capital projects are appropriately identified and managed. These are prioritized based on the VI and the performance investigation program is being expanded to include global issues such as probabilistic seismic assessments, consistent with international practices.
 - ◆ The Dam Safety Capital Projects Group undertake performance investigations and initiate capital works and Generation Project Delivery manage Dam Safety related capital projects.
- Regular update reporting takes place quarterly to the Capital Projects Committee of the Board. Dam Safety Capital Projects Group and Generation Project Delivery meet monthly to discuss projects’ status, progress and issues. Final reports are provided by Project Delivery once projects are completed.

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- ◆ While the delivery of capital projects is robust, there is no formal feedback process to Dam Safety staff outside of the Dam Safety Capital Projects Group on the status of capital projects and performance investigations as well as process of rating the deficiencies.
- There are currently 36 Dam Safety related capital projects underway in the following phases; Initiation (3), Identification (12), Definition (3), Implementation (7) and In-Service (11).
 - ◆ Of the 7 projects in the Implementation phase, management indicate the majority are forecasted to complete below budget and on schedule.
 - ◆ Of the 11 in-service projects, most achieved the original in-service target dates. Six spillway gate projects required additional funding during the implementation phase. This was primarily due to increased scope definition and design complexities as the designs progressed to address BC Hydro's reliability principles.
- The owner's engineer model is in the early stages of development to address engineering resource requirements for future capital projects. It is important for BC Hydro to maintain an appropriate balance between use of consultant assistance and retaining sufficient in-house personnel with core knowledge to effectively execute and oversee technical programs.

Emergency Management relating to Dam Safety

- All elements of emergency management relating to Dam Safety are in place and meet regulatory requirements. However, these elements are not fully developed, integrated and publicly tested with downstream response agencies and communities effectively.
- The Strategic Emergency Management (SEM) group in Transmission and Distribution business group now oversees emergency management functions across BC Hydro. The SEM team currently has about 10 staff reporting to the Manager of Emergency Management.
 - ◆ The Dam Safety Group does not have a full time resource to work with the SEM group to communicate technical Dam Safety information and co-ordinate its implementation into various emergency preparedness plans.
- Current regulations requires the annual review of the Emergency Planning Guides for each dam and to submit any revisions (if necessary) to the Dam Safety Officer. The Regulator confirmed that they have been receiving regular updates and that BC Hydro is meeting regulatory requirements.
- At least fives types of emergency plans relating to Dam Safety exist in BC Hydro and some of the plans are generic and not well integrated.
 - ◆ Plans include the Generation Emergency Response Plans, Emergency Action Plans, Surveillance Response Plans, Generation Emergency Plans, Emergency Planning Guides.
 - ◆ 14 of 19 extreme consequence dams have now developed Surveillance Response Plans, and two Emergency Action Plans have been developed for Bennett Dam and in the Lower Mainland.
- Work in progress on the Life Safety Model and the Dam Safety On-Call Program will also help strengthen emergency planning efforts in BC Hydro.
 - ◆ The Life Safety Model, developed by BC Hydro assesses the loss of life and evacuation times for a range of flood events including slow rising floods, tsunamis and dam failures.
 - ◆ The Dam Safety On-Call Program provides a backup contact to the Area Dam Safety Engineers and Technologists, via notification charts in the dam's Generation Emergency Plan.

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- ❑ Outstanding work remains to proactively interact with downstream response agencies and public testing of emergency plans to ensure effective and up to date emergency preparedness of BC Hydro dams.
 - ◆ Dam Safety Group has initiated a draft Action Plan to address communication to the public in relation to Dam Safety emergency seismic preparedness on Vancouver Island; and
 - ◆ Short term actions such as lowering reservoirs, buying out properties, and public emergency planning have been proposed to the Board to incorporate risk reduction measures in lieu of capital projects.

	Recommendations	Management Action Plans
	Surveillance	
5	❑ Develop a self-assessment process consistent with the CDA guidelines. <ul style="list-style-type: none"> ◆ Implement a self-compliance program; ◆ Implement a formal Quality Assurance program on surveillance reporting that incorporates feedback at all levels and setting surveillance compliance requirements at each site. 	❑ The Director of Dam Safety will develop a self-assessment process based on guidelines currently being developed under the Dam Safety Interest Group (CEATI). Once this is available, likely by March 2015, it will be reviewed for use as a basis to develop the self-assessment process.
6	❑ Develop a strategy to foster closer interaction between Dam Safety Engineers and plant personnel to ensure a strong, coordinated approach to Dam Safety Management.	❑ A more formal schedule of required meetings will be arranged by June 30, 2014.
7	❑ Address further testing of outlet facilities and include preparation of missing maintenance instructions.	❑ Requirements for testing will be developed in conjunction with Technical Services by April 30, 2015 with preparations of maintenance instructions to follow.
	Civil Maintenance (CM)	
8	❑ Develop a formal Civil Maintenance strategy that includes: <ul style="list-style-type: none"> ◆ An approach to ensure all CM work is integrated and processed through a common database such as Passport. ◆ A formal rating and prioritization process. 	❑ The Director of Dam Safety will discuss with EVP Generation, the strategy and resource requirements to address this recommendation by June 30, 2014.
9	❑ Ensure the deficiencies related to monitoring of reservoir levels, at some dams, are quickly addressed.	❑ The Director of Dam Safety will discuss with the respective Plant Managers what needs to be done to address the deficiencies related to monitoring of reservoir levels. Planned completion date by March 31, 2015.

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	Recommendations	Management Action Plans
10	<ul style="list-style-type: none"> Further develop the flow mechanism (e.g. penstocks, valve flow gates) testing program to determine inspection methods, scheduling, condition status and prioritized rectification. 	<ul style="list-style-type: none"> Management acknowledged that water conveyance system testing needs to be addressed in a manner similar to spillway gates testing. Development of testing requirements will be done by March 2015 and testing will follow in future years.
Performance investigations & Project Delivery Process		
11	<ul style="list-style-type: none"> Ensure communication to the Dam Safety Group on the deficiency rating and updating process; as well as provide feedback on the status of capital projects and performance investigations. 	<ul style="list-style-type: none"> In 2014, The Director of Dam Safety will arrange on-going feedback sessions with the Dam Safety department to ensure proper communication on the deficiency rating and updating process, and on the status of capital projects and performance investigations.
Emergency Management relating to Dam Safety		
12	<ul style="list-style-type: none"> Ensure technical dam safety information is communicated to the SEM group and properly incorporated into emergency preparedness plans. 	<ul style="list-style-type: none"> The Director of Dam Safety will appoint a single point of contact within the Dam Safety group to liaise with the SEM group, on matters relating to Dam Safety emergency management. Planned completion date by March 31, 2014.
13	<ul style="list-style-type: none"> Review existing emergency plans relating to Dam Safety and ensure they are site specific and well-integrated. 	<ul style="list-style-type: none"> The SEM group, with coordination with Dam Safety, will review the various emergency plans relating to Dam Safety to ensure they are well integrated. Planned completion date by March 2015. The Director of Dam Safety will ensure the Surveillance Response Plans are to be completed by September 2015.
14	<ul style="list-style-type: none"> Develop a strategy to facilitate the interaction with downstream response agencies and public testing of emergency plans in an effective and sensitive manner. 	<ul style="list-style-type: none"> An initiative has just begun to start this process on Vancouver Island. The Director of Dam Safety will develop a strategy with the SEM group to publicly test BC Hydro's emergency plans by March 2015.