

# **Dam Safety Review Guidelines**

**Dam Safety Section, Victoria, BC**

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**Version 2**

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## **References - Documents and Links Referenced in this Guideline**

1. [BC Dam Safety Regulations, February 2000](#)
2. Canadian Dam Association, Dam Safety Guidelines, 2007 <http://www.cda.ca/>
3. Canadian Dam Association, Technical Bulletins, 2007
4. [Inspection & Maintenance of Dams, Ministry of Environment, Lands & Parks, 1998](#)
5. [Plan Submission Guidelines, Water Stewardship Division, Ministry of Env., 2008](#)
6. Simplified Methods for Assessing Flood Capacity and Seismic Stability in BC for dams under 10 meters in height – draft available from Dam Safety Section, Victoria
7. Interim Consequence Classification Policy, February 2009
8. Hazards and Failure Modes Matrix – BC Hydro Process
9. Dam Breach Calculation for Consequence Classification Assessment, by John Croockewit, P.Eng. June 21, 2001
10. Dam Safety Review Report Template – under development, contact Dam Safety Section, Victoria
11. Design of Small Dams, US Dept. of the Interior, BUREC, Third Edition 1987
12. British Columbia Streamflow Inventory, Coulson and Obedkoff, March 1998; <http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2227>
13. Natural Resources Canada – Earthquakes <http://earthquakescanada.nrcan.gc.ca/index-eng.php>
14. Washington State Dam Safety: <http://www.ecy.wa.gov/programs/wr/dams/GuidanceDocs.html>

## **Additional References<sup>1</sup>**

Federal Energy Regulatory Commission (FERC) - Engineering Guidelines for the Evaluation of Hydropower Projects

<http://www.ferc.gov/industries/hydropower/safety/guidelines/eng-guide.asp>

Bureau of Reclamation (BUREC) - TSC Resources for Dam Safety Programs

[http://www.usbr.gov/pmts/tech\\_services/damsafety/index.html](http://www.usbr.gov/pmts/tech_services/damsafety/index.html)

Association of State Dam Safety Officials (ASDSO) – Publications & Resources

<http://www.damsafety.org/>

**Glossary of Terms** – to be completed

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<sup>1</sup> See CDA, Technical Bulletins, 2007 for a complete list of technical references.



## **1. Introduction**

This guideline, for the production of Dam Safety Reviews, has been prepared to assist dam owners and their qualified engineering consultants. The outline presented here is offered as a guide and is not the required methodology for preparing Dam Safety Reviews (DSRs). Many dam owners and engineering consultants have created their own templates for DSRs. This guide has been created with input from many sources and is intended to present the most current methodology as described in the Canadian Dam Association Guidelines and Technical Bulletins. One relatively new process in this guideline is a methodology to identify possible hazards and their associated failure modes (see Section 2.5, Dam Safety Analysis and the “[Hazards and Failure Modes Analysis](#)” on the Dam Safety web site).

Under Section 7 of the BC [Dam Safety Regulation](#), owners of dams classified as High or Very High Consequence of Failure are required to undertake periodic DSRs. Please see Schedule 1 of the Dam Safety Regulations, “Downstream Consequence Classification Guide” and Schedule 2 to determine the frequency for preparing DSRs. The [Canadian Dam Association](#) (CDA) defines a Dam Safety Review as:

“A comprehensive formal review carried out at scheduled intervals to determine whether an existing dam is safe, and if it is not safe, to determine what improvements are required.”

### **1.1 Dam Owner Responsibility and Consequence Classification**

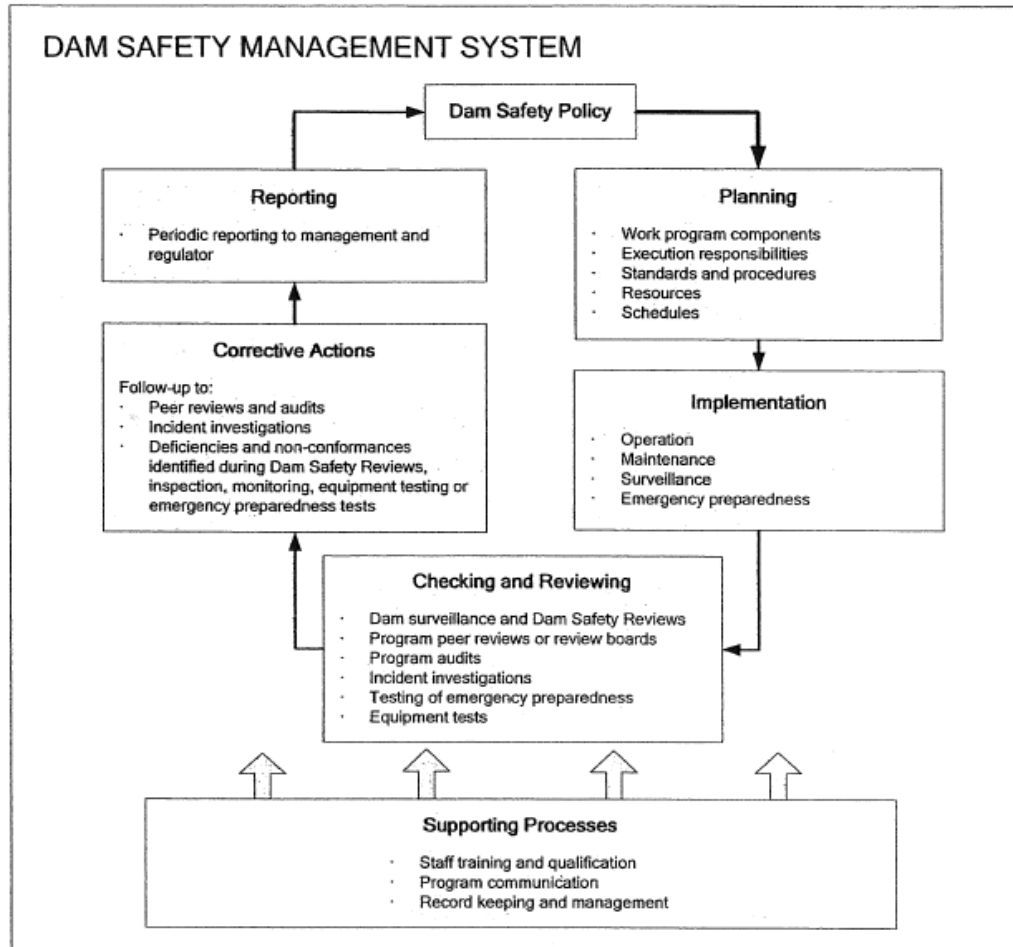
There are currently 257 High Consequence dams and 31 Very High Consequence dams in British Columbia. If the water stored behind any of these dams is released suddenly as the result of a dam failure, there would likely be loss of life, significant social and economic loss or severe environmental damage to the area downstream. Dam owners are responsible and liable for any damage caused by the failure or mis-operation of their works. Dams must be constructed to engineering standards which exceed the standards applied to most other infrastructure. In British Columbia, the Canadian Dam Association Guidelines set the standard for design, construction, operation, maintenance and surveillance of dams. The BC Dam Safety Regulations specify dam owner requirements such as inspection frequency and reporting alterations, hazards or abandonment of dams to the Dam Safety Officer and others. See the “[Downstream Consequence Classification Guide](#)” on the Dam Safety web site.

All dams in the provincial dam database have been classified by Dam Safety Officers based on available information about the dam and the downstream area. Many dam owners have undertaken a dam breach analysis and have submitted this information to the Dam Safety Officer to confirm or revise the consequence classification.

### **1.2 Getting Started**

A Dam Safety Review is a significant investment for many small dam owners. The cost can be substantially reduced by having a Dam Safety Program (a dam safety management system) in place prior to starting the process of commissioning a DSR. The first step should be to assemble all the available design and construction information as well as records of inspections, operation, maintenance and any past problems at the dam. The “Inspection and Maintenance of Dams” Guidelines, available as a free binder, or from our web site, is a good source of information on inspecting and maintaining your dam and provides templates for an inspection check list as well as operation, maintenance and surveillance (OMS) manuals and emergency preparedness plans (EPPs). Periodic updates are made to our guidelines; please check our web site for the latest information available or contact your Dam Safety Officer.

The current standard for Dam Safety Management is described in the 2007 CDA Guidelines Section 2. This section is written for large dam owners, but the basic principles apply to all dams. An outline for a Dam Safety Management System is described in Figure 2-2 and is copied below. Most of the essential elements of the Dam Safety Management System are already requirements of the Dam Safety Regulation for High and Very High Consequence Dams.



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<sup>2</sup> 2007 CDA Guidelines - Figure 2-2: Overview of an Owner's Dam Safety Management System

Dam owners should keep in mind that there is currently no requirement for owners to have a Professional Engineer undertake the annual formal inspections (unless specifically requested by the Dam Safety Officer) but, a Professional Engineer “qualified in dam safety analysis” **must** prepare the Dam Safety Review.

A sample Terms of Reference for the commissioning of a DSR is included with this guideline in Appendix 1. Owners who are already aware of one or more deficiencies with their dam may elect to add a section to the Terms of Reference that would require the engineer to confirm the deficiency and undertake a preliminary design for rehabilitation. The preliminary design could take into account any other deficiencies uncovered during the DSR and rehabilitation projects could be combined. For example, if it is already known that the spillway will not pass the inflow design flood; excavated material from the spillway rehabilitation could be used for stabilization work.

**Dam Safety Review Process:** *To be completed.*

**1.3 Dam Safety Review Report:** The Dam Safety Review will be summarized in a Dam Safety Review Report. It will list the problems at the dam, their priority and recommendations for what should be done next (see Section 3).

If the owner or engineering consultant is considering rehabilitation construction which is not considered maintenance or emergency work, the “[Plan Submission Requirements](#)” guidelines should be obtained from our Dam Safety web site or from the Dam Safety Officer.

## **2. Scope and Content of the Dam Safety Review**

The information in this section of the Dam Safety Review Guidelines is based on the 2007 Canadian Dam Association Guidelines, Section 5, Dam Safety Review. The information has been simplified from the CDA Guidelines somewhat so that it is applicable to smaller dams as well as the large dams. The Dam Safety Review Engineer (DSRE) should have a working knowledge of the CDA Guidelines and the associated CDA Technical Bulletins.

We recommend that the DSREs use the general questions in Sections 2.5, 2.6 and 2.7 to focus their review and then use the check sheet in Appendix 2 to answer specific questions and prioritize any deficiencies identified. Some of the expectations listed in the check sheet are not applicable for smaller dams. DSREs should use their discretion to determine which questions are applicable; the check sheet can be modified to suit the dam. We would appreciate any feedback from the DSREs about their experience using Section 2 in combination with Appendix 2.

### **2.1 General**

The scope of a Dam Safety Review may vary from dam to dam, depending on the consequence classification, complexity of design, previous assessments, age, etc. However, it should cover all aspects required to demonstrate that (i) the dam is safe, operated safely, and maintained in a safe condition; and (ii) surveillance is adequate to detect any developing safety problem. If safety cannot be demonstrated, the review engineer should identify the deficiencies. The review generally includes site inspection, review of all relevant documentation, and interviews with operating and maintenance staff. Records of any dam safety incidents since the previous review and records of follow-up actions should be reviewed. The flow discharge equipment should be tested at this time as well if appropriate. If a previous Dam Safety Review was conducted, the review engineer may elect to structure the DSR as an audit of the previous information, ensuring that it is complete and up to date.

### **2.2 Site Inspection and Dam Owner Interview**

All Dam Safety Reviews should include a site inspection. A sample “[Dam Inspection checklist for Dam Safety Reviews](#)” is provided in the Dam Safety web site. The inspection should include all works at the dam site, an assessment of the reservoir, in particular reservoir debris and a tour of the downstream area to re-assess the downstream consequence classification. If the dam is exposed to conditions other than those on the day of the inspection (full or drawn down reservoir, extreme cold, wind storm, etc.) the review engineer should review inspection records or speak to the owner about any anomalies which may have occurred during those conditions. The dam owner should be interviewed about the following: operating and maintenance issues or incidents, equipment or system issues, dam performance, and any issues involving integration with other dam owners or stakeholders. An evaluation of the overall dam management system should be made, see Section 2.9.

### 2.3 Data and Records

Ideally, a Dam Safety Review will include an assessment of the construction methodology, conditions and practices used for construction of the dam. Unfortunately, construction reports, design plans and records are not available for many older dams. Every effort should be made to find all available information about the dam. As noted in Section 1, Introduction, the dam owner should keep complete records as part of an effective Dam Safety Program and should ensure that all available information is collected before the Dam Safety Review is started. Please note that the Regional Dam Safety Officer or the Dam Safety Section in Victoria may have information on the dam that is important for the DSR.

### 2.4 Consequences of Failure

During the Dam Safety Review, the potential consequences of dam failure need to be reviewed. The primary reasons for a change in the consequences are new development downstream, re-evaluation of the inundation area or identification of environmental or socioeconomic consequences previously unaccounted for.

A revised consequence classification table, with 5 consequence categories was developed for the 2007 CDA Guidelines. Until further notice, for the purpose of reviewing dam design criteria only, the 1999 CDA Guidelines may be used for dams constructed before 2008. The main reason for this is the change in the Inflow Design Flood Level recommended for the “High” consequence dams in the 2007 CDA Guidelines. Please see the “[Interim Consequence Classification Policy for dams in British Columbia](#)”, February 2009, on the Dam Safety web site.

Requirements for **dam owners** under the Dam Safety Regulation (inspection frequency, OMS & EPP requirements, etc.) are based on Schedule 1, Downstream Consequence Classification Guide, Dam Safety Regulation, February 2000.

### 2.5 Dam Safety Analysis

Safety analysis of the dam system should include the internal and external hazards, failure modes and effects, operating reliability and dam response. A Hazard and Failure Mode Matrix ([HFMM](#)) with [instructions](#) is provided in the Dam Safety web site to assist the review engineer to analyse the safety of the dam. This matrix allows the DSR engineer to examine only the failure modes that apply to each specific dam. Analysis of failure modes for smaller dams will be reduced considerably. The DSR engineers may wish to use their own [hazards and failure modes analysis](#) process, or, create a simplified failure modes analysis using the failure modes identified in Section 3 of the “[Inspection & Maintenance of Dams](#)” guideline on the Dam Safety web site. Please note that failure due to dam management is not included in Section 3 of the *Inspection & Maintenance of Dams* guideline and it should be included with the failure modes analysis.

For many small older dams there was no sophisticated analysis done when the dam was designed and constructed. The review of the design as it relates to the present condition of the as-constructed, as-operated dam should include the following as appropriate.

1. Construction Records: Does the as-constructed dam conform to design assumptions and intent? Adequacy of dam and foundation materials.
2. Adequacy of derived extreme events, floods, and earthquakes for which the dam was designed, taking into account any extreme events that may have occurred since the commissioning of the dam. A draft guide “Simplified Methods for Assessing Flood Capacity and Seismic Stability in BC for dams under 10 meters in height” is available from Dam Safety Section, Victoria
3. Capacity of all waterways and conduits to discharge their design flows safely, pass the inflow design flood (IDF) and to draw down the reservoir in an emergency.
4. Structural stability and seepage and erosion resistance of all water barriers and their foundations under normal and extreme loading.
5. Adequacy of design for all gates, valves and other control equipment under normal operation and following extreme events. Adequacy to deal with specific site issues that have or may occur such as debris blockages, rodents, ice conditions, etc.
6. Operating rules under various conditions and their conformance with design intent and criteria.
7. Adequacy of design, construction, and operation to address potential failure modes.
8. If there is more than one dam on this system, does the operation of any dams affect the safety of the others?

## **2.6 Operation, Maintenance and Surveillance**

The documentation of operation, maintenance, and surveillance, along with compliance, should be reviewed. The following questions should be considered. See Check Sheet Appendix 2:

- Have safe operating procedures been developed, documented and followed? Are there contingency plans for dealing with the failure of components?
- Are all facilities needed for dam safety including precipitation and water level gauges, snow survey stations, and dam monitoring instrumentation, maintained in satisfactory condition in accordance with established procedures?
- Are the methods and frequency of surveillance and monitoring adequate to detect any unsafe condition in a timely manner? Have monitoring data been analyzed regularly and used to ensure prompt detection of any potentially unsafe conditions in the dam, associated water containments, or reservoir slopes?
- Are there adequate debris management procedures to ensure that debris does not block spillways or reduce their discharge capacity?
- Are ice management procedures in cold regions adequate to ensure that the spillways are not blocked by ice when they are needed?
- Are maintenance procedures and their frequency adequate for the dam and its components, including gates and other discharge facilities, power supply, cranes, motors and hoists, and foundation drains?
- Are there adequate vegetation control procedures?
- Is the flow control equipment maintained in good working order and tested regularly to ensure it will function reliably when called on to operate?

- Are incidences of malfunction promptly reported, investigated, and addressed to prevent recurrence?
- Is the backup equipment (such as alternative power supplies) that is called for in the contingency plans available and readily accessible?

The review engineer can assess compliance with the documented procedures by auditing the operation, maintenance, and surveillance records, having discussions with site personnel, and judging the state of maintenance and site conditions during the site visit.

The Dam Safety Review should address the testing of equipment required to operate discharge facilities (including backup equipment and emergency power supply) needed for safe passage of the IDF and any other flood that could endanger the dam. If the discharge gates and equipment have been tested or operated within a year and adequate documentation is available, a review of such testing or operation records may be adequate. Otherwise, the testing can be carried out during the Dam Safety Review.

## **2.7 Emergency Preparedness**

The emergency preparedness plans and emergency response procedures must be reviewed. The Dam Safety Review should determine answers to the following questions:

- Is emergency preparedness at an appropriate level and adequately documented?
- Are the warning systems, training, and emergency response plans adequate?
- Is the frequency of testing appropriate?
- Are there processes in place for document control?
- Are the notification lists maintained? Is there a robust process in place to keep them updated and communicated, especially for external contacts?
- Are findings and lessons learned from incidents or emergency drills properly documented and followed up within a reasonable time?

**2.8 Public Safety and Security** The DSRE should verify that public safety hazards at the dam have been identified and addressed. The DSRE should verify that the operating equipment is secured against vandalism or operation by unauthorized individuals. The dam owner has the right to secure the works under Section 3 (4) of the DS Regulation.

## **2.9 Dam Safety Management System**

For the purposes of this guideline, the review of the management of the dam may be limited to a review of the OMS & EPP from the perspective of overall management of the dam & reservoir. As noted in Section 1.2, Figure 2-2 from the 2007 CDA Guidelines provides a overview of a dam owner's Dam Safety Management System.

### **3 Dam Safety Review Report**

At the completion of the Dam Safety Review, the review engineer should present the dam owner with a formal report containing the conclusions of the review and recommendations that will help the owner fulfill the responsibility for dam safety and comply with regulations. This report should:

- Document the review.
- Quantify deficiencies in the structures.
- Draw attention to any non-compliance with policies, guidelines, or standards and to any other issues requiring follow-up so that priorities can be readily established for safety improvement, remedial measures, or additional investigations.
- Identify any additional steps needed for safe operation, proper maintenance, and adequate surveillance of the dam.
- Report on information gaps in past documentation, identify potential deficiencies, and suggest further actions or investigations that may be needed to confirm conformance with dam safety requirements.
- List all records reviewed and location of records.

The initial methods of analysis used in the review, or the data available, may be insufficient to clearly demonstrate an acceptable level of safety for the dam, discharge facilities, or reservoir slopes. If additional work is needed to evaluate and document dam safety, the Dam Safety Review report should include recommendations for more extensive analysis or investigations to provide adequate data for analysis.

Therefore, the essential output of the safety review is one or more of the following conclusions:

- The dam clearly meets all safety requirements.
- The dam clearly does not meet some safety requirements (list the deficiencies or non-conformances and recommended actions).
- It is uncertain whether or not some requirements are met (list the areas of doubt and the actions needed to reach a firm position).

It is the responsibility of the dam owner to review the Dam Safety Review report. The review engineer or dam owner is required to forward a copy to the Dam Safety Officer as per Section 7 (2) of the Dam Safety Regulations.

*It is the intention of the Dam Safety Section to prepare a template for the Dam Safety (Review) Report which will be included in this guideline as Appendix 3. Please check the Dam Safety web site for the most recent version of this guideline.*



**Appendix 1      Sample Terms of Reference for Commissioning a Dam  
Safety Review**



## **TERMS OF REFERENCE – Dam Safety Review for *Sample Dam(s)***

### **Notes:**

**1. Information in italics and brackets is content that is either: optional, a sample or an alternative method of expressing something.**

**2. These Terms of Reference can be modified to suit the complexity of the dam design.**

### **TR1 INTRODUCTION**

Dam Owner Inc requests proposals for suitably qualified, experienced professional engineers to conduct Dam Safety Reviews (DSRs) on the following dam(s) in *(year)*:

Sample Dam – *(Very) High consequence (earthfill) dam located (between Town A and Town B)*

Sample Dam 2 – *High consequence (concrete gravity) dam located (near Town A on Vancouver Island)*

Appendix 1 provides further information on the dams. The Dam Safety Review is to cover all saddle dams, the reservoir rim, the spillway, the plunge pool, and all water conveyance structures, including all points of flow control. *(The owner can elect to include the powerhouse or other appurtenant structure as appropriate).* The consequence classifications for the dams are based on the 2000 B.C. Dam Safety Regulation. *(note that the consequence classifications in the 2007 CDA Dam Safety Guidelines are different – see the Interim Guide to Consequence Classifications available from the BC Dam Safety Program.)*

*(This paragraph should be added if previous studies of the dam(s) have been undertaken.)* The dam(s) has been the subject of previous detailed analyses *(dam safety review, deficiency investigations and/or other studies including safety improvements).* The *(detailed analysis)* has been enclosed on CD or attached as a pdf for reference or available on request from Dam Owner Inc. The *(detailed analysis)* is provided for general information only. *(It is not to be copied and must be returned to Dam Owner Inc by (date)).*

### **TR2 OBJECTIVE**

The purpose of the DSR is to determine the currency and adequacy of the safety management of the dam and to identify any deficiency in the safety of the dam. The Review must meet the requirements of the BC Dam Safety Regulation and the reviewer should utilize the CDA Guidelines as the principle source of standard engineering practice for dam safety. *(The owner can add a statement about the reviewer meeting the requirements of Owner Inc's corporate safety policy)*

### **TR3 SCOPE & SCHEDULE**

#### **.1 General**

A Dam Safety Review should include at the outset the identification of possible hazards and their associated failure modes of the dam, based on an examination of available information. From the understanding of hazards and associated failure modes, the existing safety management of the dam shall be evaluated in terms of its adequacy and currency against a set of pre-defined principles.

The outcome of the DSR is either:

- Confirmation that all things necessary to confirm the safety of the dam are in place, are current and appropriate, and are being followed; or

- Identification of issues/deficiencies for further investigation in a separate project.

No detailed review of design calculations is to be carried out, and no detailed analysis is required on the dam's performance capability, surveillance data or reservoir operations (*unless Dam Owner Inc wants a known deficiency analyzed and rehabilitation options identified*).

*(If there are any deficiency investigations or capital projects underway, the process for dealing with that (within the context of this review) should be addressed here.)*

## **.2 Schedule**

The following tables provide a format for the applicant to estimate the number of hours and specify the approximate schedule to carry out the work. The review may be carried out by a single DSR Engineer. With two engineers, the DS Review Engineer is expected to be involved for at least 30% of the total hours.

The work should be carried out in three phases as shown in the following two tables. The hours shown for each phase in Table 1 are indicative only, and can be adjusted by the DSR Engineer as long as the approved overall budget is not exceeded.

**Table 1 – Phases and Approximate Hours to complete the Dam Safety Review(s)**

Phase	Description	DS Review Engineer	Engineering (specify)	Administration
1	Reconnaissance and Document Review	(xx)	(xx)	
2	Detailed Work	(xx)	(xx)	(xx)
	Site Visit	(xx)	(xx)	
3	Finalize Report	(xx)	(xx)	(xx)
<b>TOTAL</b>		<b>(xx) hrs</b>	<b>(xx) hrs</b>	<b>(xx) hrs</b>

**Table 2 – Approximate Schedules of the Dam Safety Review(s)\***

Phase	Description	Sample Dam 1	Sample Dam 2	Sample Dam 3
1	Reconnaissance and Document Review	(Month(s) - Year)	(Month(s) - Year)	(Month(s) - Year)
2	Detailed Work	(Month(s) - Year)	(Month(s) - Year)	(Month(s) - Year)
	Site Visit**	(Month(s) - Year)	(Month(s) - Year)	(Month(s) - Year)
3	Finalize Report	(Month(s) - Year)	(Month(s) - Year)	(Month(s) - Year)

\* Alternative schedules proposed may be considered.

\*\* Site visits timing requires coordination with Dam Owner Inc.

## **.3 Phase 1 – Reconnaissance & Document Review**

The project will commence with a start-up meeting (teleconferencing is possible) to scope the particular areas to be covered or excluded under this review.

The DSR Engineer (*and other Engineering support*) is expected to:

- Identify performance expectations, including flood and earthquake criteria, based on the Canadian Dam Association Guidelines (see Interim Consequence Classification Guidelines for BC as required).
- Review available documents for evidence of conformance with dam safety requirements. *(Include any of the following documents available from Dam Owner Inc and remove those that are not)* Documents include but may not be limited to:
  - Dam Safety Management Manual;
  - Dam Safety Program Manual;
  - Operation, Maintenance & Surveillance (OMS) Manual for Dam Safety;
  - Emergency Preparedness and or Emergency Response Plans;
  - Surveillance reports and memos;
  - Past Comprehensive Inspection & Review (CIR) and DSR Reports;
  - Previous Hazards and Failure Modes Studies;
  - Previous Dam Safety Expectations Studies;
  - Past Deficiency Investigation and Capital Improvement reports;
  - Current outstanding dam safety issues;
  - Completed dam safety issues;
  - Other available documents related to design, operation, maintenance, improvement, condition and performance of the dam or appurtenant works.
- Discuss the chosen hazards and failure modes methodology with Dam Owner Inc. *(Hazards and failure modes analysis is discussed in the Dam Safety Review Guidelines and a sample hazards and failure modes matrix (HFMM) is provided in the Dam Safety web site. If this HFMM is used by the DSR Engineer those hazards and failure modes that do not apply should be eliminated (with documented reasons) and justification given for including the remaining hazards and failure modes. The HFMM will be considerably reduced for smaller dams because many of the failure modes will not apply).*
- Discuss the methodology to be used to summarize and prioritize the dam safety deficiencies and non conformances from a list of all potential dam safety deficiencies. *(A "Sample Check Sheet of Dam Safety Expectations" is provided in the Dam Safety Review Guidelines in Appendix 2)* The DSR Report should be based on this list and should indicate whether or not the dam conforms to each dam safety expectation. If the available information is not adequate to draw such a conclusion, then the inadequacy of information should be noted.

At the end of Phase 1, the DSR Engineer *(and other Engineering support)* is expected to:

- Have acquired sufficient knowledge and understanding of the dam(s) to identify the hazards and failure modes applicable the dam(s) in question;
- Submit a draft "Hazards and Failures Modes Matrix" (or equivalent) specific to the dam(s), documenting the reasons why certain hazards and failure modes would not apply;
- Be technically ready to conduct technical review meetings with Dam Owner Inc staff.

#### **.4 Phase 2 – Detailed Work (including Site Visit)**

This is the most intensive phase of the project. In Phase 2, the DSR Engineer *(and Other Engineering support)* is expected to:

- Determine the dam's conformance with the set of dam safety expectations, including:
  - Evaluate, review and audit Dam Owner Inc's knowledge base by meeting with Dam Owner Inc personnel involved in dam safety management, operation,

maintenance, surveillance, performance evaluation or other relevant activities.

- Conduct a site visit to inspect each dam and review on-site documents.
- Identify any additional dam safety requirements to enhance risk management.
- Review past reports and studies to ensure that all past recommendations and issues have been properly documented.
- Identify and document deficiencies and non-conformances in safety management of the dam and any deficiency in the safety of the dam, using the Dam Safety Expectations check sheet (or equivalent) as a guide. Deficiencies are to be characterized as Actual, Potential or Non-Conformance (as defined in the Dam Safety Review Guidelines, Appendix 2) and prioritized in order of importance.
- Make significant progress in the preparation of a Draft Report. (*recommended: In addition to addressing the foregoing requirements, the report should also include recommendations for dam safety improvements, further investigation of deficiencies, further studies to correct information gaps, and any other appropriate actions to improve dam safety.*)

Dam Owner Inc's support to the DSR Engineer (*and Other Engineering support*) in Phase 2 will generally be limited to the coordination of technical meetings and site visits. The DSR Engineer is expected to provide his/her own safety equipment (including hard hat, steel-toed boots, safety glasses, reflective vest and if required, fall protection harness) for the site visit.

At the end of Phase 2, the DSR Engineer (*and Other Engineering support*) is expected to:

- Have obtained all information required to complete the DSR Report.
- Be at least 75% complete on the Draft Report.
- (*Hold a verbal presentation session summarizing findings to the Dam Owner Inc staff.*)

#### **.5 Phase 3 – Finalize Report**

In Phase 3, the DSR Engineer (*and Other Engineering support*) is expected to:

- Complete the Draft Report;
- Within 2 weeks of completing Phase 2, submit 2 hard copies or one electronic copy of the Draft Report to Dam Owner Inc for review;
- Consider Dam Owner Inc comments for inclusion in the Final Report;
- Prepare electronic and hard copies of the Final Report.

At the end of Phase 3, the DSR Engineer is expected to:

- Submit the required numbers of Final Reports in both hard copies and CD-ROM's (see Section TR4).
- Provide comments, if any, on improvements of the DSR process.

#### **TR4 DELIVERABLES**

The final Dam Safety Review Report shall be prepared by the consulting firm with its own cover design, signature page, headers and footers, etc.

*(Further requirements are as follows:*

- *Hard Copies*
  - *# bound copies of the final DSR report*
  - *An unbound original of the final DSR report.*
- *CD-ROM's*
  - *To be created using Adobe Acrobat<sup>R</sup> 5 or 7, with links between Table of Contents, report texts, tables, figures and appendices;*
  - *4 copy-protected CD ROMs containing the final DSR report;*
- *All electronic files of the final DSR report shall be submitted, with appropriate "readme" files.*
- *Return all documents borrowed for the DSR study to Dam Owner Inc.)*

Quality assurance of the final DSR report will be the responsibility of the DSR Engineers and their associated consulting firm.

#### **TR5 DAM SAFETY ENGINEERS**

The **Dam Safety Review Engineer** must:

- Hold current registration as a Professional Engineer;
- Have at least 10 years of experience in the design, construction, performance evaluation and operation of dams;
- Be familiar with the BC Dam Safety Regulation and the CDA Dam Safety Guidelines;
- Have not participated in the design, construction or safety management (including deficiency investigations and capital improvement projects) of the specific dam. Note: it may be appropriate for the same company to do the DSR but the Dam Safety Review Engineer should not have participated in the design, construction or safety management of the dam(s).

The Dam Safety Review Engineer is expected to direct and be involved throughout the Dam Safety Review process.

If additional support, such as technical specialist consultation, quality assurance and word processing from others is required, these shall be indicated in the Letter of Proposal with their corresponding fees and disbursements.

#### **TR6 PROPOSAL REQUIREMENTS**

*(To be completed using Dam Owner Inc. standard requirements for requests for proposals.)*

### **Appendix 1 – Information about the Sample Dam(s)**

*(This information should be drawn from the Operation, Maintenance & Surveillance Manual.)*



## Appendix 2 Sample Check Sheet for a Dam Safety Expectations – Deficiencies and Priorities

### CHECK SHEET OF DAM SAFETY EXPECTATIONS

#### Definitions of Deficiencies and Non-Conformances

- 1) Deficiencies:
  - a) Actual – An unacceptable dam performance condition has been confirmed, based on the CDA Guidelines, BC Dam Safety Regulations or other specified safety standard. Identification of an actual deficiency generally leads to an appropriate corrective action or directly to a capital improvement project
    - i) **(An)** Normal Load – Load which is expected to occur during the life of a dam.
    - ii) **(Au)** Unlikely Load – Load which could occur under unusual load (large earthquake or flood)
  - b) Potential – There is a reason to expect that an unacceptable condition might exist, but has not been confirmed. Identification of a potential deficiency generally leads to a Deficiency Investigation
    - i) **(Pn)** Normal Load – Load which is expected to occur during the life of a dam.
    - ii) **(Pu)** Unlikely Load – Load which could occur under unusual load (large earthquake or flood)
    - iii) **(Pq)** Quick – Potential deficiency that cannot be confirmed but can be readily eliminated by a specific action.
    - iv) **(Pd)** Difficult - Potential deficiency that is difficult or impossible to prove or disprove.
- 2) Non-Conformances: Established procedures, systems and instructions are not being followed, or, they are inadequate or inappropriate and should be revised.
  - a) Operational (**NCo**), Maintenance (**NCm**), Surveillance (**NCs**)
  - b) Information (**NCi**) – information is insufficient to confirm adequacy of dam or physical infrastructure for dam safety.
  - c) Other Procedures (**NCp**) – other procedures, to be specified

<b>DAM SAFETY EXPECTATIONS</b>		<b>Yes</b>	<b>N/A</b>	<b>No</b>	<b>An/Au</b>	<b>Pn/ Pu/ Pq/ Pd</b>	<b>NCo/ NCm/ NCs</b>	<b>NCi/NC p</b>
<b>1</b>	<b>Dam Safety Analysis</b>							
1.1	Records relevant to dam safety are available including design documents, historical instrument readings, inspection and testing reports, operational records and investigation results.							
1.2	The Dam is classified appropriately in terms of the consequences of failure including life, environmental, cultural and third-party economic losses (As of 2009 consequence classifications for dams in BC are based on the BC Regulation and CDA Guidelines – see Interim Consequence Classification Policy, February 2009 on the Dam Safety web site)							
1.3	inundation study adequate to determine consequence classification. Flood and “sunny day” scenarios assessed.							
1.4	Hazards external and internal to the dam have been defined							
1.5	The potential failure modes for the dam and the initial conditions downstream from the dam have been identified							
1.6	All other components of the water barrier (retaining walls, saddle dams, spillways, road embankments) are included in the dam safety management process.							
1.7	The MDE selected reflects current seismic understanding							
1.8	The IDF is based on appropriate hydrological analyses							
1.9	The dam is safely capable of passing flows as required for all applicable loading conditions (normal, winter, earthquake, flood)							
1.10	The dam has adequate freeboard for all applicable operating conditions (normal, winter, earthquake, flood)							
1.11	The analyses are current							
1.12	The approach and exit channels of discharge facilities are adequately protected against erosion and free of any obstructions that could adversely affect the discharge capacity of the facilities							

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1.13	The dams, abutments and foundations are not subject to unacceptable deformation or overstressing							
1.14	Adequate filter and drainage facilities are provided to intercept and control the maximum anticipated seepage and to prevent internal erosion							
1.15	Hydraulic gradients in the dams, abutments, foundations and along embedded structures are sufficiently low to prevent piping and instability							
1.16	Slopes of an embankment have adequate protection against erosion, seepage, traffic, frost and burrowing animals							
1.17	Stability of reservoir slopes are evaluated under all conditions and unacceptable risk to public safety, the dam or its appurtenant structures is identified.							
1.18	The need for reservoir evacuation or emergency drawdown capability as a dam safety risk control measure has been assessed.							
<b>2</b>	<b>Operation, Maintenance and Surveillance</b>							
2.1	Responsibilities and authorities are clearly delegated within the organization for all dam safety activities							
2.2	Requirements for the safe operation, maintenance and surveillance of the dam are documented with sufficient information in accordance with the impacts of operation and the consequences of dam failure							
2.3	The OMS Manual is reviewed and updated periodically when major changes to the structure, flow control equipment, operating conditions or company organizational structure and responsibilities have occurred.							
2.4	Documented operating procedures for the dam and flow control equipment under normal, unusual and emergency conditions exist, are consistent with the OMS Manual and are followed							
	<b>Operation</b>							
2.5	Critical discharge facilities are able to operate under all expected conditions.							
a.	Flow control equipment are tested and are capable of operating							

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as required.							
b. Normal and standby power sources, as well as local and remote controls, are tested.							
c. Testing is on a defined schedule and test results are documented and reviewed.							
d. Management of debris and ice is carried out to ensure operability of discharge facilities							
2.6 Operating procedures take into account:							
a. Outflow from upstream dams							
b. Reservoir levels and rates of drawdown							
c. Reservoir control and discharge during an emergency							
d. Reliable flood forecasting information							
e. Operator safety							
<b>Maintenance</b>							
2.7 The particular maintenance needs of critical components or subsystems, such as flow control systems, power supply, backup power, civil structures, drainage, public safety and security measures and communications and other infrastructure have been identified							
2.8 Maintenance procedures are documented and followed to ensure that the dam remains in a safe and operational condition							
2.9 Maintenance activities are prioritized and carried out with due consideration to the consequences of failure, public safety and security							
<b>Surveillance</b>							
2.10 Documented surveillance procedures for the dam and reservoir are followed to provide early identification and to allow for timely mitigation of conditions that might affect dam safety							
2.11 The surveillance program provides regular monitoring of dam performance, as follows:							
a. Actual and expected performance are compared to identify							

<b>DAM SAFETY EXPECTATIONS</b>	<b>Yes</b>	<b>N/A</b>	<b>No</b>	<b>An/Au</b>	<b>Pn/ Pu/ Pq/ Pd</b>	<b>NCo/ NCm/ NCs</b>	<b>NCi/NC p</b>
deviations							
b. Analysis of changes in performance, deviation from expected performance or the development of hazardous conditions							
c. Reservoir operations are confirmed to be in compliance with dam safety requirements							
d. Confirmation that adequate maintenance is being carried out							
2.12 The surveillance program has adequate quality assurance to maintain the integrity of data, inspection information, dam safety recommendations, training and response to unusual conditions							
2.13 The frequency of inspection and monitoring activities reflects the consequences of failure, dam condition and past performance, rapidity of development of potential failure modes, access constraints due to weather or the season, regulatory requirements and security needs.							
2.14 Special inspections are undertaken following unusual events (if no unusual events then acknowledge that requirement to do so is documented in OMS).							
2.15 Training is provided so that inspectors understand the importance of their role, the value of good documentation, and the means to carry out their responsibilities effectively.							
2.16 Qualifications and training records of all individuals with responsibilities for dam safety activities are available and maintained							
2.17 Procedures document how often instruments are read and by whom, where the instrument readings will be stored, how they will be processed, how they will be analyzed, what threshold values or limits are acceptable for triggering follow-up actions, what the follow-up actions should be and what instrument maintenance and calibration are necessary.							
<b>3 Emergency Preparedness</b>							
3.1 An emergency management process is in place for the dam including emergency response procedures and emergency preparedness plans with a level of detail that is commensurate with the consequences of failure.							

<b>DAM SAFETY EXPECTATIONS</b>		<b>Yes</b>	<b>N/A</b>	<b>No</b>	<b>An/Au</b>	<b>Pn/ Pu/ Pq/ Pd</b>	<b>NCo/ NCm/ NCs</b>	<b>NCi/NC p</b>
3.2	The emergency response procedures outline the steps that the operations staff is to follow in the event of an emergency at the dam.							
3.3	Documentation clearly states, in order of priority, the key roles and responsibilities, as well as the required notifications and contact information.							
3.4	The emergency response procedures cover the full range of flood management planning, normal operating procedures and surveillance procedures							
3.5	The emergency management process ensures that effective emergency preparedness procedures are in place for use by external response agencies with responsibilities for public safety within the floodplain.							
3.6	Roles and responsibilities of the dam owner and response agencies are defined.							
3.7	Inundation maps and critical flood information are appropriate and are available to downstream response agencies.							
3.8	Exercises are carried out regularly to test the emergency procedures.							
3.9	Staff are adequately trained in the emergency procedures.							
3.10	Emergency plans are updated regularly and updated pages are distributed to all plan holders in a controlled manner.							
<b>4</b>	<b>Dam Safety Review</b>							
4.1	A safety review of the dam ("Dam Safety Review") is carried out periodically based on the consequences of failure.							
<b>5</b>	<b>Dam Safety Management System</b>							
5.1	The dam safety management system for the dam is in place incorporating:							
a.	policies,							
b.	responsibilities,							
c.	plans and procedures including OMS, public safety and security,							
d.	documentation,							

<b>DAM SAFETY EXPECTATIONS</b>	<b>Yes</b>	<b>N/A</b>	<b>No</b>	<b>An/Au</b>	<b>Pn/ Pu/ Pq/ Pd</b>	<b>NCo/ NCm/ NCs</b>	<b>NCi/NC p</b>
e. training and review,							
f. prioritization and correction of deficiencies and non-conformances,							
g. supporting infrastructure							
5.2 Deficiencies are documented, reviewed and resolved in a timely manner. Decisions are justified and documented							
5.3 Applicable regulations are met							



## **Appendix 3     Dam Safety Review Report Template**

To be completed.....

