Dam Safety Guidelines

Inspection and Maintenance of Small Dams

BRITISH COLUMBIA

Contents

NOTE: ***These guidelines are intended to inform owners or operators of small dams of general aspects of inspection and basic maintenance in order to assess and address certain unsafe conditions. The information in this document describing possible solutions to deficiencies is intended for guidance only and may not be appropriate in all situations. Dam owners who encounter deficiencies should obtain the services of a professional engineer to assess the problem and take appropriate remedial action.***

1 Introduction

British Columbia has more than 1,800 active dams licensed under the ***Water Sustainability Act***. Most of B.C.'s 1,800 dams are small earthfill dams used for agricultural, conservation and drinking water purposes.

Dams in B.C. must be authorized by a water licence issued under the *Water Sustainability Act*, and owners must meet requirements specified in the ***Dam Safety Regulation***[1], which was proclaimed in February 2000 and revised in 2016.

These guidelines are produced by the B.C. Dam Safety Program to give owners of small dams – less than 15 metres in height – a basic understanding of their liabilities and responsibilities with regard to inspection, operation, maintenance and reporting procedures for their dams. It also provides a basis for discussion between a dam owner and dam safety program staff. The guidelines include a self-help section that dam owners can use to assess and deal with specific problems they may have on their dam.

Many of the templates in the appendices can be downloaded from the B.C. ***Dam Safety*** website[2] or are available from a dam safety program office (see Appendix 1). Check the dam safety website regularly for updates.

These guidelines offer general advice on how to avoid an issue with acceptable maintenance or how to deal with it if it becomes a potential safety hazard. If your dam has a potentially dangerous deficiency such as serious cracks or sinkholes, you must alert a regional dam safety officer immediately. You should also consider hiring a qualified professional engineering consultant who has the knowledge and experience with dam construction and remedial work.

Information about professionals who are qualified to conduct work related to dam safety is available from the dam safety officer or through Engineers and Geoscientists BC.[3]

1 B.C. *Water Sustainability Act* Dam Safety Regulation 2016. ***www.bclaws.ca/civix/document/id/complete/statreg/40_2016***

2 Dam Safety ***https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/dam-safety***

3 Engineers and Geoscientists BC ***https://www.egbc.ca/***

2 What is a Safe Dam?

A SAFE DAM IS ONE WHICH PERFORMS ITS INTENDED FUNCTIONS WITHOUT IMPOSING UNACCEPTABLE RISKS TO THE PUBLIC BY ITS PRESENCE. – *U.S. Bureau of Reclamation*

Dams by their very nature create risks but these can be substantially minimized if owners conduct regular inspections and routine maintenance so they can recognize and resolve problems early. As well as minimizing risk and potential liability, keeping a dam safe protects the owner's investment and ensures secure access to a water source.

Dam safety is becoming increasingly important as more people and development move into rural areas. Climate change in B.C. indicates a greater likelihood of extreme storm events and rapid spring melt of snow.

The most common causes of an earthfill dam failure are overtopping, foundation defects and slope instability, cracking, and inadequate maintenance. Concrete dam failures are usually related to poor design, construction or materials; foundation or abutment erosion that leads to overturning or sliding; abutment or foundation failure due to over-stressing; or structural failure of concrete unable to sustain imposed loads.

2.1 Owner Responsibilities

TESTALINDEN DAM *Failure (near Oliver) June 13 2010.*

TESTALINDEN DAM *Failure (near Oliver) June 13 2010. In 2010, a torrent of mud and debris caused widespread destruction near Oliver after the earthfill Testalinden Dam on an irrigation reservoir failed after heavy rains. A review found that the owner had ignored warnings about the dam's condition.*

Dam owners – whether they are companies or individuals – are responsible for ensuring their dam and appurtenant works are structurally sound, are operated safely, and are maintained adequately. This is to prevent loss of life, damage to the environment, or adverse social impacts such as loss of communal water supply or impact on infrastructure such as roads or buildings.

Dam owners determine the classification of their dam based on failure consequences, as set out in Schedule 1 of the *Dam Safety Regulation* (Appendix 2), and must review this classification annually. Classifications range from low, which implies a failure would have minimal social, environmental or economic impacts, to extreme, which implies possibly many deaths, major environmental impacts and extremely high economic losses affecting public or private infrastructure. More details about dam classifications in B.C. can be found in *Downstream Consequence of Failure Classification Interpretation Guidelines*.

RIGHTS AND RESPONSIBILITIES OF APPLICANTS AND OWNERS

A WELL-DEVELOPED DAM SAFETY MANAGEMENT PLAN is not only good practice, it is also required by law. Under the *Water Sustainability Act* of British Columbia, a water licence is needed to build a structure for the storage of water – and the person who holds that licence is considered the owner of the dam. Section 29 of the Act states:

1. The following persons must exercise reasonable care to avoid damaging land, works, trees or other property of another person:
   a. *an applicant for an authorization, change approval, drilling authorization or permit;*
   b. *the holder of an authorization, change approval, drilling authorization or permit;*
   c. *a person who, in accordance with the regulations or an order of the comptroller, a water manager or an engineer, makes changes in and about a stream or diverts or uses, including stores, water.*
2. A person referred to in subsection 1 a, b or c must properly inspect, maintain and repair works constructed, operated or used by the person,
   a. *in accordance with any prescribed requirements,*
   b. *in accordance with an order, and*
   c. *in a manner that ensures that the works do not cause a significant risk of harm to public safety, the environment, land or other property.*
3. When an authorization, change approval or permit that authorizes the construction or use of works is abandoned, cancelled or expires, the holder or former holder, as applicable, of the authorization, change approval or permit must ensure that the works are deactivated or decommissioned in accordance with the regulations and orders.
4. A person referred to in subsection 1 a, b or c is liable to owners of land or premises for damage or loss resulting from the construction, maintenance, use, operation or failure of the person's works.
5. Subject to subsections 1 to 4, a holder of a licence for a power purpose, a storage purpose, a waterworks purpose or an irrigation purpose may fell and remove any tree, and remove any rock or other thing, that endangers the holder's works.

A sound dam safety management system with regular inspections and maintenance minimizes risk and potential liability as well as protecting the owner's investment and ensuring the water source is secure for its intended use.

To achieve this, dam owners are expected to:

- Conduct site surveillance and formal inspections according to Schedule 2 of the Dam Safety Regulation (See Appendix 3), and record and interpret the information.
- Follow a regular routine maintenance schedule, and make required repairs in a timely manner.
- Prepare plans and manuals where required, including:
  - » Operation, Maintenance & Surveillance Manual (see section 4 of these guidelines).
  - » Dam Emergency Plan (see section 3.3), including revisions to contact information as needed.

- Test mechanical components and electrical and communication equipment annually unless otherwise specified in the Operation, Maintenance & Surveillance Manual.
- Operate the dam in a manner that will give the greatest assurance of safety.

The B.C. Dam Safety Program has posted a *Plans Review Checklist for Proposed and Existing Dams* on its website to help reviewers consider all aspects of proposed or existing dam design. It should be used in conjunction with the *Plan Submission Guidelines for the Construction and Rehabilitation of Dams*.

2.2 Provincial Dam Safety Program

The failure of even a relatively small dam can have severe consequences, and smaller dams are more likely to fail because of inadequate dam design and poor construction. Owners may also lack the knowledge and skills to operate and maintain their dam or may not have the resources to maintain them properly.

The B.C. Dam Safety Program was set up in 1967 to help dam owners reduce risks associated with the design, construction, operation, maintenance, removal and/or decommissioning of dams. Dam safety officers are designated under the *Water Sustainability Act*, and work with dam owners to ensure compliance with the *Dam Safety Regulation*.

The program has an office in Victoria and eight regional offices (see Appendix 1). In general, dam safety officers in Victoria handle dams more than nine metres in height, often owned by local authorities, companies and power utilities, and regional dam safety officers support the owners of smaller dams.

Some of the key duties of the dam safety officers:

- Lead education and training activities to ensure dam owners have access to current information.
- Make sure dam owners comply with regulation requirements; conduct audits when applicable.
- Help owners who have concerns about the safety of their dam.
- Review plans for construction, alterations and decommissioning or removal of dams.
- Participate in enforcement of regulations when necessary.
- Provide limited assistance and support to dam owners during serious dam emergency incidents.

Serious issues such as slides, longitudinal/transverse cracking or foundation weakness should be reported immediately to the dam safety officer. See Appendix 1 for a list of contact numbers, or you can send general questions or comments to ***damsafety@gov.bc.ca***.

2.3 Types of Dams

The two most common types of dam worldwide are earthfill dams and concrete dams.

Earthfill dams, also known as embankment dams, are the most common type in British Columbia. They are made of natural excavated materials such as mineral soils or rock, usually obtained at or near the dam site. These dams do not have any binding materials – the mass weight and the strength of the dam construction material is what holds back the reservoir water.

The W.A.C. Bennett Dam in northwest B.C. is as high as a 60-storey building and two kilometres long, and holds back the 360 kilometres of Williston Lake, the largest reservoir in North America.

Concrete dams include a variety of structures, including gravity, slab and buttress, multiple arch, and single arch dams. Masonry dams may be considered as a gravity structure with many joints.

A concrete gravity dam has a wide base – usually about three-fourths of the height of the dam – and the weight counteracts the water pressure. When the water pushes against it, the weight of the dam pushes downward to counteract the water pressure.

The **CLEVELAND DAM** *in North Vancouver is a concrete dam that supplies about 40 per cent of the Lower Mainland's fresh drinking water.*

SMOKY CREEK DAM, *a small concrete dam near Nelson*

2.4 Main Dam Components

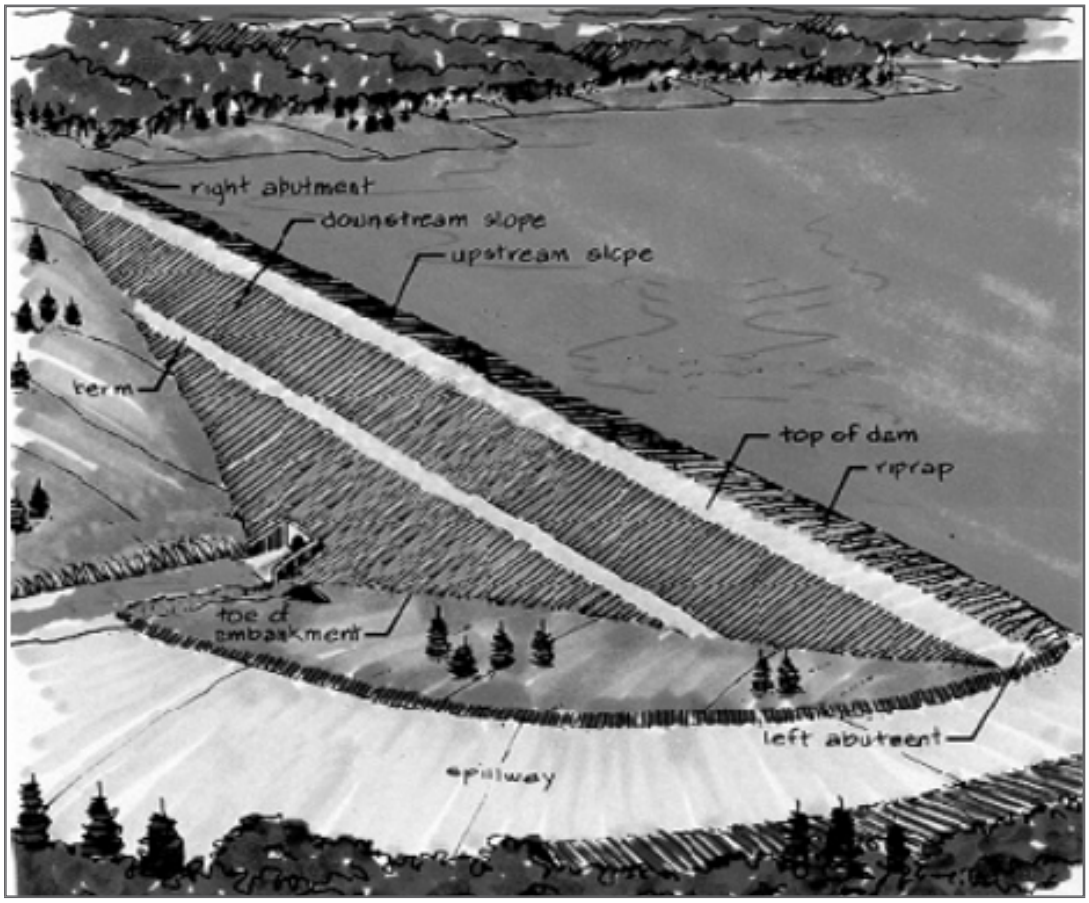


FIGURE 1: *Principal parts of an embankment dam*

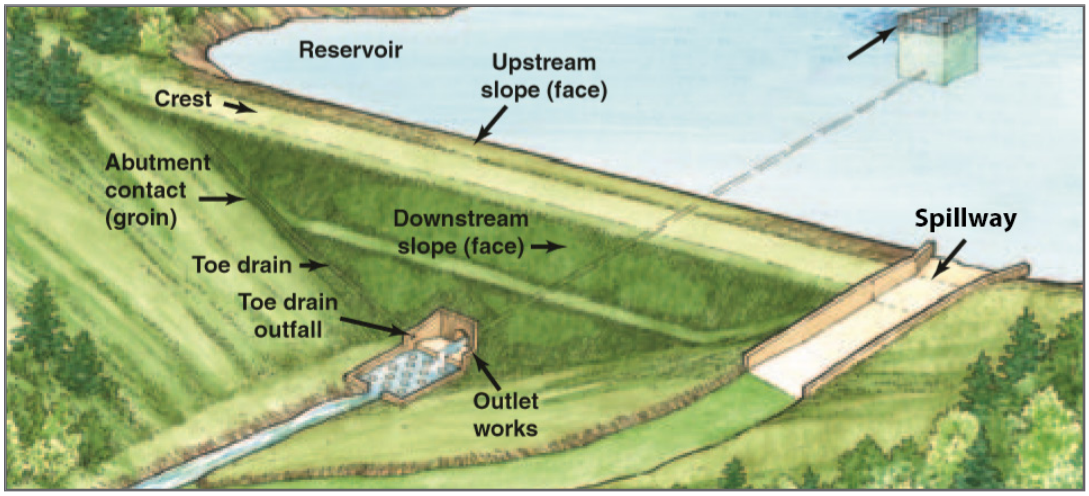


FIGURE 2: *Typical components of an embankment dam*

- The **ABUTMENTS** are on either side of the valley against which the dam is constructed.
- The **DOWNSTREAM SLOPE** is the face of the dam away from the reservoir water, and the upstream slope is the part of the dam in contact with the reservoir water.
- The **CREST** is the top or uppermost surface of the water-retaining structure of the dam. It can include a road or walkway, or the non-overflow section of the dam.
- **RIPRAP** is a layer of well-graded broken rock – larger than gravel – that is generally placed on the upstream slope or along a watercourse as protection against wave action, erosion or scouring.
- The **SPILLWAY** is a channel, conduit, tunnel or other structure that is designed to allow a controlled release of water from the reservoir. Some spillways may include weirs or gates to adjust flow.
- The **TOE OF DAM** is the junction of the downstream face of the dam with the foundation or surface on which the dam structure is placed. The farthest upstream point of a dam is sometimes called the heel.

You will find more definitions in Appendix 10, Glossary of Terms.

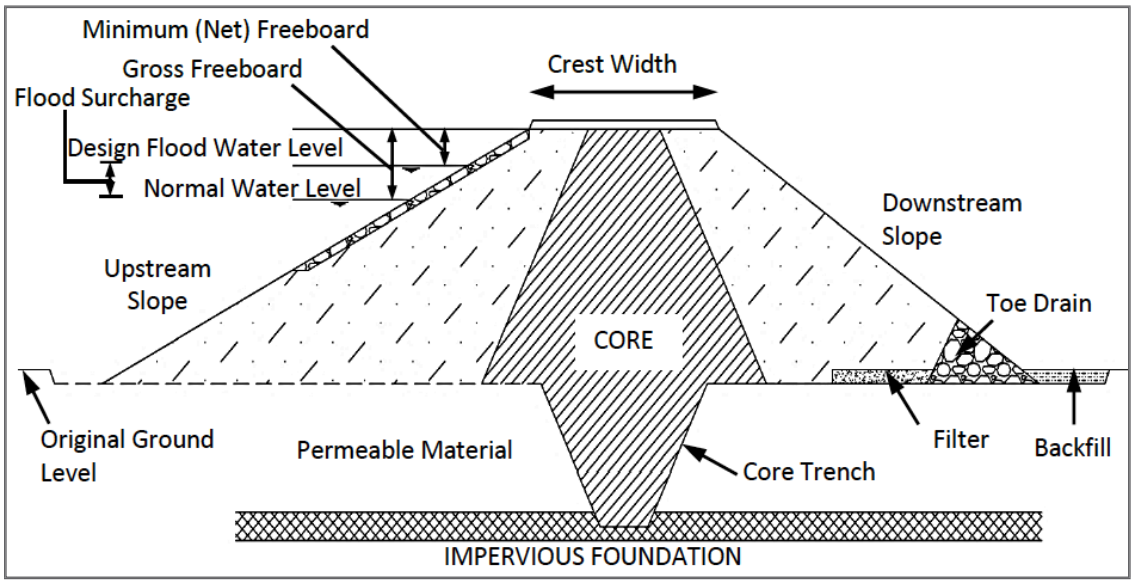


FIGURE 3: *Cross section of a zoned filled dam*

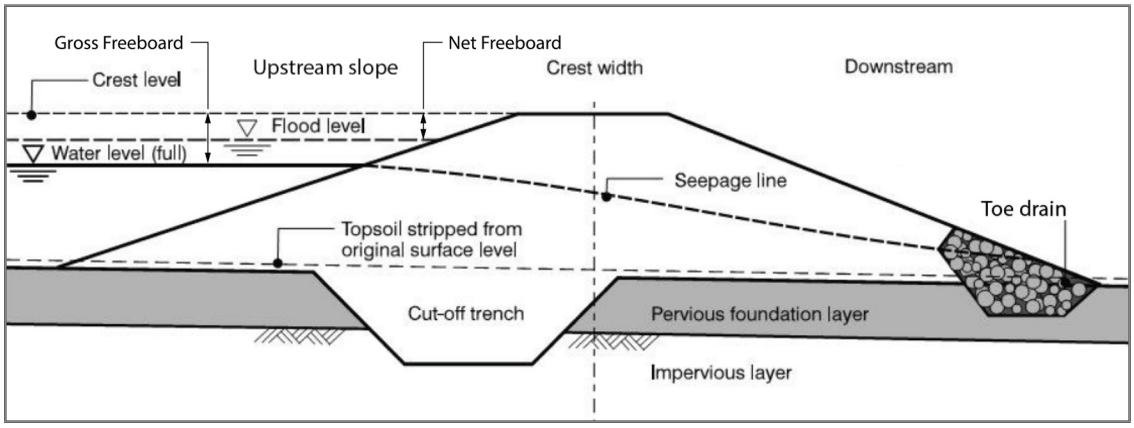


FIGURE 4: *Cross section of a homogeneous dam.*

2.5 Dam failures in British Columbia

The failure of the South Fork Dam in 1889 after weeks of heavy rains killed 2,200 people and destroyed much of Johnstown, Pennsylvania, making it one of the worst man-made disasters in North America.

Dam failures in B.C. include:

- In 1912, one man drowned and there was extensive property damage at Union Bay near Nanaimo when a poorly designed and maintained dam servicing a coal washing and screening plant failed.
- In 1941, there was severe downstream damage to homes and orchards when the 10-metre Ellis Creek Dam, which had recently been raised to triple the reservoir capacity, failed near Penticton. Although the dam had just been inspected, a review showed the new portion of the dam had been poorly designed. This dam has since been rebuilt. With recent development, if this dam were to fail today, there would be significantly greater damage and likely loss of life.
- In 1995, 48 head of cattle were killed, 1.5 kilometres of public road destroyed, 100 acres of hay field damaged, and 700,000 cubic metres of debris introduced into the Quesnel River when a five-metre earthfill irrigation dam failed, likely the result of a faulty culvert spillway.

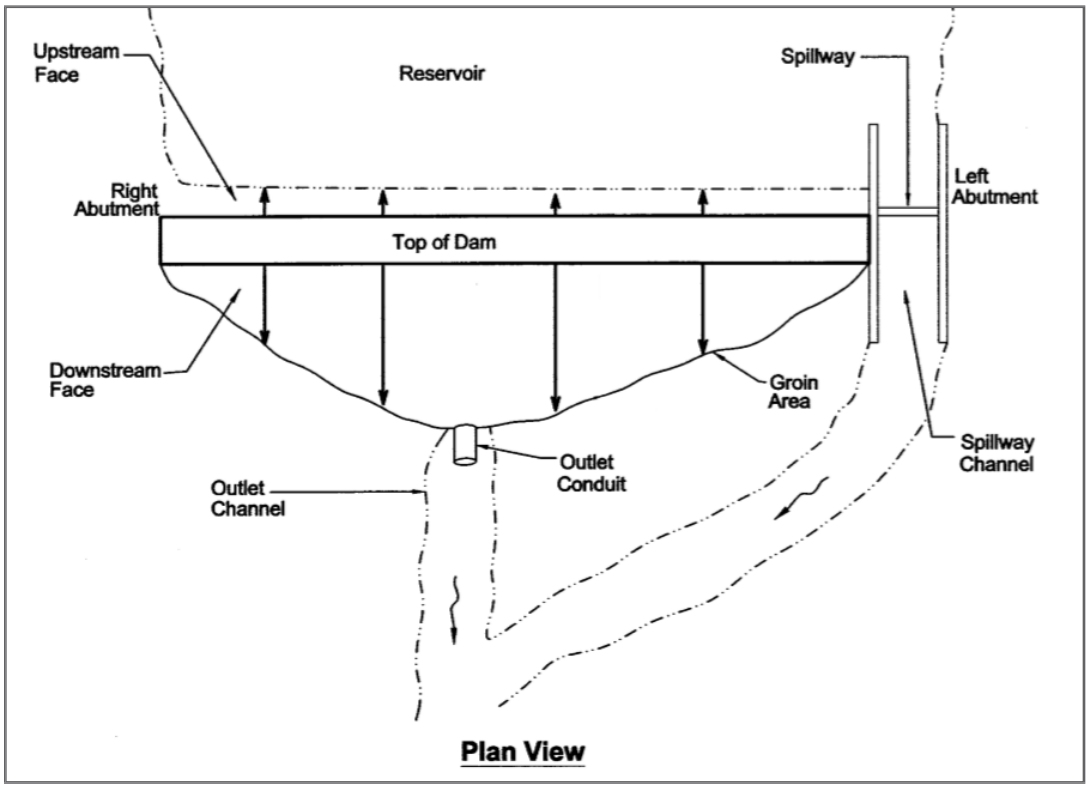


FIGURE 5: *Typical plan view of an embankment dam*

3 Inspections and Plans

Owners are responsible for the completion of inspections and the submission of plans, as set out in schedule 2 of the *Dam Safety Regulation*. A good dam safety management system includes a regular inspection program as an integral part of a proper maintenance program. It identifies problems and/or unsafe conditions so they can be repaired, avoiding more serious issues or possible dam failure.

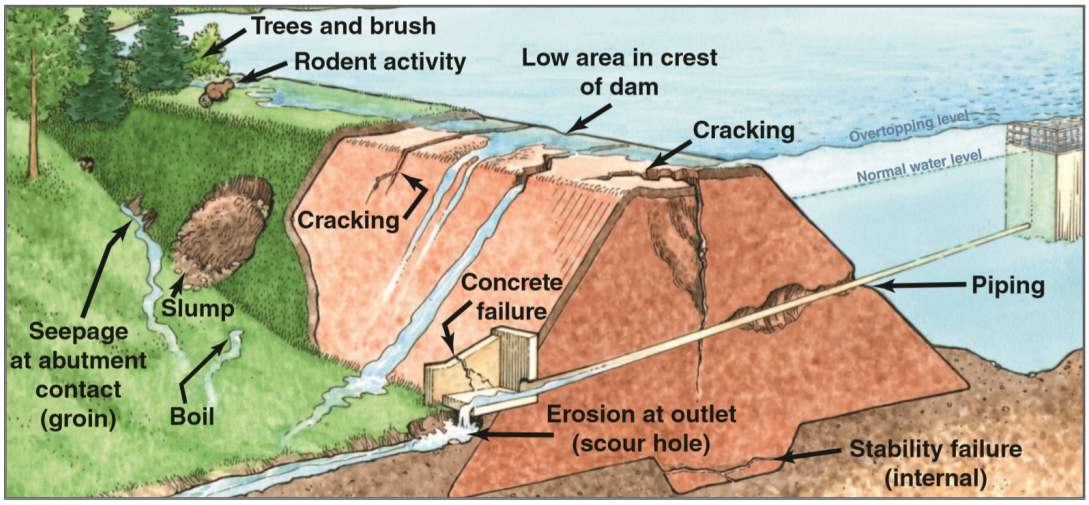
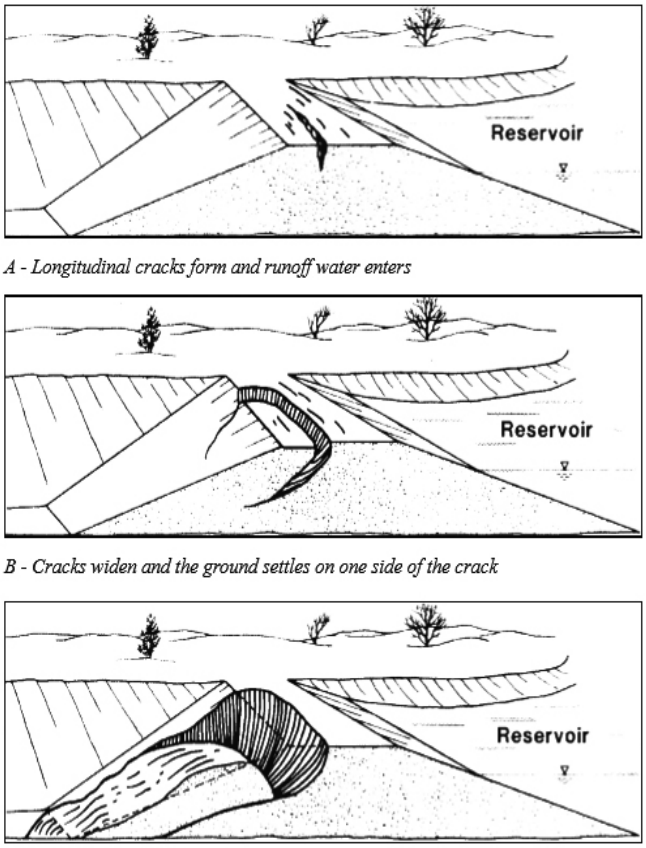


FIGURE 6: POTENTIAL PROBLEM INDICATORS
Examples of issues to watch for during inspections so they can be corrected or reported promptly.

DAM OWNERS SHOULD FOLLOW THE SIMPLE RULE to gather and record facts that may have an impact on the safety of the dam:

- **S** - Sketch the deficiency, and note its important characteristics.
- **M** - Measure the deficiency.
- **P** - Photograph the deficiency or describe its characteristics in writing.
- **L** - Locate the deficiency relative to a standard reference point.

3.1 Surveillance Inspections



A - Longitudinal cracks form and runoff water enters

B - Cracks widen and the ground settles on one side of the crack

C - The slope fails

FIGURE 7: *This diagram shows how a longitudinal crack can lead to dam failure if action is not taken quickly enough.*

Regular surveillance inspections are the most efficient and economical means of assuring the safety and long life of a dam. It allows owners to examine all dam surfaces carefully to assess the condition, identify issues early and resolve them before they become more serious. These guidelines provide enough information to allow most dam owners to complete this type of inspection.

The frequency of surveillance inspections is based on the dam's consequence classification, and is set out in Schedule 2 of *Dam Safety Regulation* (see Appendix 3). It ranges from weekly if the consequences of failure are extremely high to quarterly if they are minimal.

Inspection systems should be set up so they can be repeated consistently. Start by printing off or downloading a copy of the relevant Site Surveillance form (there are two forms available, for an earthfill dam or a concrete dam – see Appendices 4 and 5) and modifying it to meet the specific needs of your dam. Bring along basic equipment such as a clipboard, tape measure/ruler, field notebook, camera, pencil and flashlight.

Prior to the inspection you should review any notes and photographs from earlier inspections, and drawings of the dam construction if they are available. This allows you to compare the current state of the dam with conditions when it was built or at the time of previous inspections. Photographs are extremely helpful because changes are sometimes subtle and may not be obvious for months or even years. Be alert to the fact that potential problems can sometimes be obscured by excessive vegetation.

Measure conditions that might change, such as seepage readings, and watch for anything that could signal potential issues, such as reservoir levels, operational conditions, outlet and spillway releases.

Inspect all components of the dam, and watch for:

- Excessive vegetation, rutting or cracks on the crest.
- Erosion, riprap displacement, cracks or animal activity on the upstream and downstream slopes.
- Cracks, slides, erosion or seepage on the downstream slope.
- Seepage, sand boils or standing water at the downstream toe.
- Seepage, erosion or instability of the abutments.
- Problems with the operation of gates or control valves associated with the spillway and/or low level outlet.

Inspect the inlet and outlet structures, paying close attention to the internal condition of any conduit, pipe or access well. Record details of anything that has changed since the last inspection, such as new or increased erosion areas, settlement, cracks, seepage or wet areas.

Surveillance inspections generally are done:

- According to a schedule included in the owner's Operation, Maintenance & Surveillance Manual.
- Late spring or early summer when the reservoir is full and seepage under, through or around the dam is most noticeable.
- Late summer or early fall when the reservoir is drawn down, allowing a more thorough inspection of the upstream face.
- After severe weather events such as heavy rain, wind, severe icing or rapid snowmelt.
- After a severe seismic event.

Specific deficiencies are best viewed as follows:

- Slope failure – after a rapid drawdown of the reservoir.
- Displacement of slope protection – after severe wind, ice or heavy rain storms.
- Crest settlement – after heavy rain.
- Crest rutting – in the autumn.
- Downstream slope seepage – when the reservoir is full.
- Downstream slope failure – when the reservoir is full and seepage is evident.
- Rodent burrows in the downstream slope – spring and fall.
- Downstream toe seepage – during high reservoir levels.
- Downstream toe bulging, which can indicate a slide – after high reservoir levels.
- Tree or shrub growth on the upstream or downstream slope, crest or downstream toe – year-round.

If the inspection identifies serious problems, alert the dam safety officer and consider the need to retain the services of a qualified professional engineering consultant.

3.1.1. Earthfill Dam Inspections

FIGURE 8: LONGITUDINAL CRACKING
Regular surveillance inspections can spot issues such as longitudinal cracking so they can be addressed or reported promptly.

FIGURE 9: *Dam sloughing caused by longitudinal cracking and vertical displacement*

Since external surfaces of an earthfill dam often provide clues about the condition of its interior, inspections should begin with a thorough examination of all exposed surfaces.

Check the embankment for evidence of displacement, cracks, sinkholes, springs and wet spots. If not corrected, any of these can lead to eventual failure of the dam. The downstream slope is the area where evidence of developing problems appears most frequently so keep it free from obscuring vegetation.

Check abutments for seepage or erosion, especially in the abutment/embankment contact zone. Also look for other signs of abutment instability such as cracking or material displacement.

If the reservoir is maintained at its full supply level, you can only inspect the upstream slope above the water level. Lower portions of the slope can be inspected when the water level is low, usually in late summer or early fall.

See Appendix 4 for a site surveillance checklist for earthfill dams.

Section 6 of these guidelines provides advice on actions to take if you find a potential problem during an inspection

3.1.2 Concrete Dam Inspections

Concrete dams are immune to many issues that affect earthfill dams, such as erosion and piping failures. However, the symptoms of failure are also not as obvious, so there can be little or no advance warning of potential issues.

Concrete is a mixture of cement, water and aggregate. One potential issue in a concrete dam is an alkali-aggregate reaction when cement reacts with a chemical in some aggregates, producing a silica gel that can cause the concrete to expand. This creates tension in the concrete, and may causing cracking.

Other things to watch for when inspecting a concrete dam are: deterioration in the concrete or masonry; surface defects; displacement or misalignment of adjoining blocks; differential movement; or leakage and seepage.

Concrete dams transfer a substantial weight load to the abutments and foundation. The dam itself may be sound, but if the natural terrain cracks, crumbles or moves in a massive slide, its support is lost and the dam may fail. Impending failure is hard to detect because the initial movements are often very small.

See Appendix 5 for a site surveillance checklist for concrete dams.

Section 6 of these guidelines provides advice on actions to take if you find a potential problem during an inspection.

3.1.3 Appurtenant Works Inspections

Appurtenant works such as outlets, spillways and gates are not actually part of the dam but they can be critical components in ensuring it operates safely and efficiently.

3.1.3.1 SPILLWAY

The spillway provides an evacuation route for water that entered the reservoir after storms or snow melt. If it is not large enough or becomes blocked with debris, the water could go over the top of the dam – this is the main cause of many dam failures.

Look for obstructions such as vegetation, debris, beaver dams, snowdrifts or landslide deposits. If the spillway is excavated in sandy, deteriorated granite, clay or silt deposits, make sure there is no erosion or deterioration. Check for cracks in the channel caused by uneven foundation settlement, slab displacement or excessive earth or water pressure.

FIGURE 10: *Obstructed spillway channel*

FIGURE 11: *Inspecting a spillway training wall*

3.1.3.2 OUTLET

As shown in figure 13, there are many kinds of outlets. These control mechanisms and conduits are usually submerged and are not easily accessible. This allows for serious issues to develop unnoticed that can lead to embankment failure, such as inoperable control works or conduit deterioration.

Proper inspection requires advanced planning so outflows can be shut off and inundated areas pumped out. The use of a remotely operated camera is a recommended practice for outlet inspection.

FIGURE 12: *Typical outlet gate valve*

Outlet works should be inspected for the following deficiencies:

- Damaged or inoperable control valve or gate mechanism.
- Silted inlet – you can usually prevent a buildup of silt by periodically operating the outlet.
- Deteriorated inlet and outlet structures (usually made with concrete).
- Piping along the conduit that can result in internal erosion and sloughing – it can appear as a low area or sinkhole on the crest.
- Dirty/murky or silty water flowing from around the conduit, which could signal internal erosion (piping).
- Erosion at the low level outlet.
- Corrosion or perforations along the conduit.
- Joint separations along the conduit, particularly if it is made of corrugated steel pipe using seepage collars.

NOTE: In most cases services of a qualified professional engineering consultant will be required to recommend corrective action for these problems.

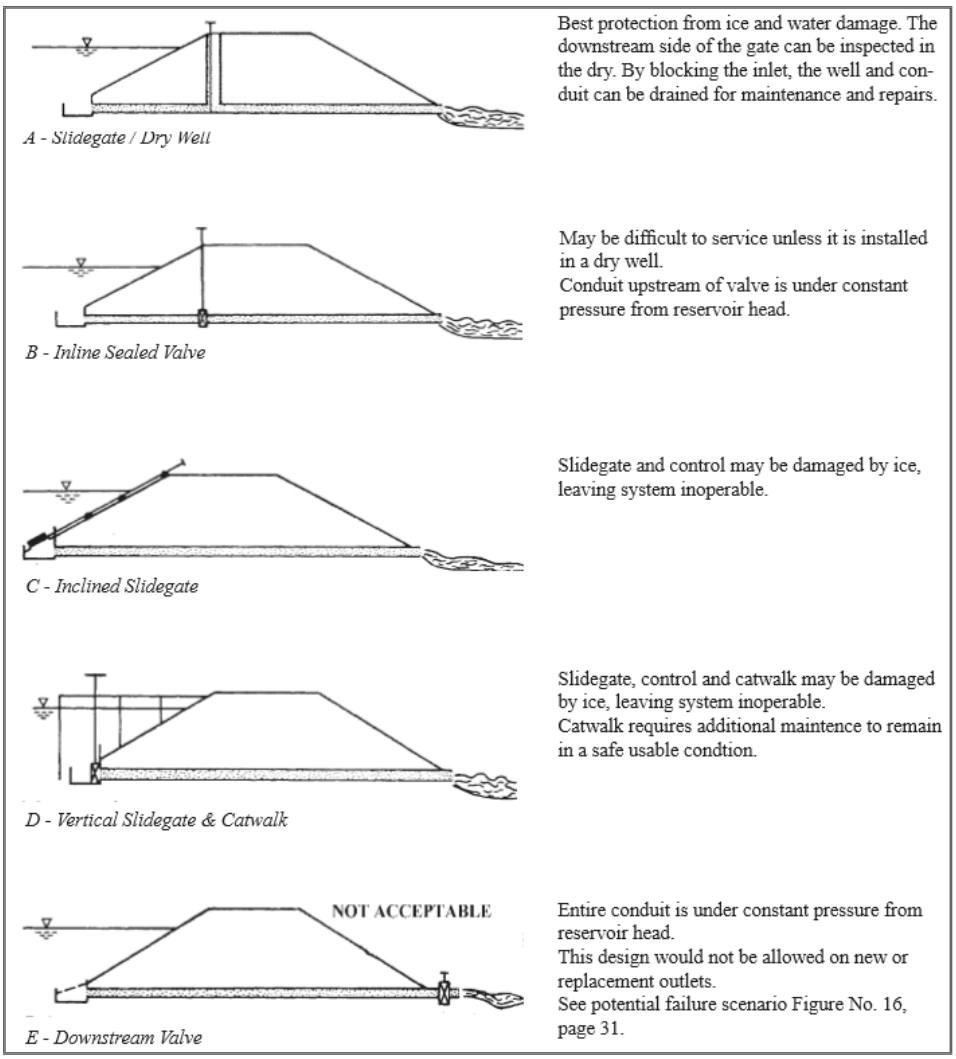


FIGURE 13: *Most common types of low level outlet controls*

There are many kinds of outlets – as noted, some are easier to inspect and repair than others.

The downstream valve outlet shown in Diagram E, of figure 13 is not appropriate for a safe dam because it is under constant pressure and cannot be inspected unless the reservoir is drained.

3.1.3.3 GATES

Properly operating outlet gates are essential if the reservoir is used for a recreation or fish propagation purpose when the water does not have to be released. In these cases, the gates are the only means for an emergency drawdown if it becomes necessary.

You should confirm that the operating controls or gates work as intended. Problems that should be addressed as soon as possible include rusted or non-lubricated valve stem threads; debris lodged in the intake; vandalism of the gate controls; or ice damage.

3.1.3.4 SIGNS

The *Dam Safety Regulation* requires that some dam owners post signs with 24-hour emergency contact information so they can be alerted immediately if an issue or problem is found by someone. As part of your inspection, make sure the signs are accurate and can be read clearly, with no overgrowth or vandalism. Appendix 6 lists dam signage requirements.

See Appendices 4 and 5 for site surveillance checklists for earthfill and concrete dams.

Section 6 of these guidelines provides advice on actions to take if you find a potential problem during an inspection.

3.2 Formal Inspections

More thorough formal inspections are conducted annually for all dams except those classified as extreme consequence classification, in which case it is twice a year. These inspections are conducted by the dam owner or a staff person responsible for safety surveillance, and the results are noted in the site surveillance checklists (see Appendices 4 and 5), which the owner should keep on record. It is recommended that these annual formal inspections take place at varying times of the year, one year during high reservoir levels the following year during low reservoir level and so on.

For most dam owners, the site surveillance checklist is all that is required. If the dam is more complex and the consequence classification is high, very high or extreme, the dam safety officer may request a more comprehensive Formal Annual Inspection (see Appendix 7).

NOTE: Downstream conditions should be evaluated at the same time as the formal inspection to ensure the consequence classification has not changed. If it has, the new classification must be reported to the dam safety officer. If there is no change to the classification, the owner should retain the information for their records.

3.3 Dam Emergency Plan

While the failure of a properly built and maintained dam is extremely remote, it is important that dam owners have a Dam Emergency Plan to deal with any urgent issues. See Appendix 8 for an *Information Sheet: Guide & Template for Preparing a Dam Emergency Plan in British Columbia*.

The Dam Emergency Plan needs to identify the dam failure evacuation area, persons in the immediate vicinity of the dam, and the local emergency authority contact information. A portion of the Dam Emergency Plan needs to be given to the local emergency authority for use in their preparations of an emergency situation. It also should contain details for the plan user to know what can be done at the dam site to manage an emergency situation, and include information such as the location of emergency equipment.

The information in the emergency plan must be readily available and up to date.

3.4 Dam Safety Review

The dams with the highest consequence classification must carry out a Dam Safety Review – every 10 years for dams at the high and very high classification and every seven years for the extreme classification. Guidance for undertaking a Dam Safety Review is available under technical resources on the B.C. Dam Safety Program website.

4 Operation, Maintenance and Surveillance Manual (OMS)

The Operation, Maintenance and Surveillance Manual (OMS) provides the information necessary for an inexperienced or untrained person to perform all the functions required to operate the dam safely and, in the case of an emergency, protect or notify people in the immediate vicinity downstream and the local emergency authority. It can minimize the need for costly repairs, and assures the safety of the dam, continuous operation of the reservoir, the efficient use of the water, and an extended useful life for the structure. *The Operation, Maintenance, and Surveillance Manual template* is found in Appendix 9.

The OMS includes items such as the operation of the outlet gate and the spillway, the surveillance inspection schedule for the dam, performance monitoring and results, interpretation of the results of surveillance and monitoring, dam emergency procedures and performance of all required maintenance.

It includes the water licence number and a copy of the licence, as well maps, plans and other sources to provide a clear picture of the location, makeup and function of each part of the dam. Photographs taken during inspection should be kept on file for comparison and reference.

Other items in the OMS include:

- a detailed description of how to access the dam along with a map;
- overall dimensions of the dam and spillway;
- outlet configuration and operation;
- drainage systems and outfall locations; and
- location and capacity of inflow and outflow structures.

The OMS includes the location and detail of locations of instrumentation.

Once the OMS has been written, reviewed and found acceptable by the dam safety officer, the owner must identify who will carry out the various duties and provide each person with a copy of the completed document. The owner must review the OMS annually to ensure contact information is up to date, and must send revised copies to all manual holders.

4.1 Outlet and Reservoir Operating Instructions

The OMS must include a clear step-by-step set of instructions for operating the outlet system, listing the proper sequence to be followed in opening and closing gates, gate usage for low and high flow, opening ranges where excessive vibration is experienced, and operating problems particular to a specific gate.

The OMS needs to clearly describe the general operation of the reservoir, including the regulation of inflow and outflow structures. These will address maximum storage elevations to be observed in anticipation of spring runoff or winter/spring storms, as well as maximum and/or minimum permissible outlet releases; maximum and/or minimum reservoir storage; operation of the outlet to permit excessive spillway flows; and periodic closure of the outlet to permit a thorough outlet inspection.

NOTE: If a SCADA control system is used to remotely operate equipment or monitor flows or water levels, there must be a feedback to the controller to confirm that the desired action has occurred.

4.2 Surveillance Inspection and Maintenance Records

The OMS should identify areas that should receive special or more frequent surveillance inspections – using the site surveillance checklists in Appendices 4 and 5. Areas where there may be seepage or other issues should be kept clear of vegetation or marked permanently so they can be found during the inspections.

The benefits of the monitoring require an orderly record so the data can be used to measure and review dam performance. Instructions must be provided on how to make and record each measurement.

The OMS should also list all required maintenance work, with any special instructions for periodic maintenance so new personnel understand what needs to be done, and experienced personnel can be sure they completed the work properly.

5 Maintenance

FIGURE 14: *Shows a poorly maintained dam with excess vegetation on the slope and a broken log boom*

FIGURE 15: *Shows a well-maintained dam*

A dam and reservoir represent a substantial investment in infrastructure – and a potential public hazard. All dam owners should have an annual maintenance program to address and control problems. Talk to the dam safety officer if you have any questions related to maintenance.

Routine maintenance items include:

- removing debris;
- regrading the crest and/or access road;
- adding riprap where required;
- sealing joints in concrete facings;
- cleaning drain pipes and outfalls;
- maintaining protection for monitoring points; and
- maintaining security for operating equipment

Maintenance does not include alterations, improvements or replacements that may require authorization under the *Dam Safety Regulation*, *Water Sustainability Act*.

5.1 Earthfill Dam Maintenance

Earthfill structures require regular maintenance to control seepage and erosion that can lead to unwanted seepage paths and deterioration of the structure. Maintenance programs also include control of vegetation and burrowing animals, maintenance of riprap, crest, drainage system and instrumentation, slope stabilization, and removal of upstream debris.

5.2 Concrete Dam Maintenance

While concrete dams are often more permanent structures, their failure can be more catastrophic. There is also often little warning because the symptoms prior to failure are less obvious so the collapse can be very rapid. Routine maintenance includes repairing cracks and obvious concrete deterioration.

5.3 Appurtenant Works Maintenance

FIGURE 16: *Intake control access structure failure*

FIGURE 17: *Outlet discharge weir*

5.3.1 Spillway Maintenance

The spillway should always be kept free of obstruction, have the ability to resist erosion, and be protected from deterioration.

Log booms should be placed upstream of the spillway at the location where the flow velocity is low, to prevent debris from entering and blocking the channel. Remove accumulated floating debris from the reservoir, especially near the spillway entrance, and dispose of it above the flood water level. Remove blockages from the spillway channel such as soil, sediment and rock, and clear away beaver dams. Tall weeds and brush should be cleared periodically and trees removed as soon as they are noticed because brush and debris can get tangled in them and create an obstruction.

Clear debris from log booms periodically – if it becomes excessive, the log boom could break and the debris could obscure the spillway. Prevent future blockages by installing trash racks to capture debris.

5.3.2 Outlet Gate Maintenance

Regular operation of gates prevents the buildup of rust on contact surfaces of the operating mechanism. The simplest way to ensure continued operability of the outlet gates is to cycle all gates through their full operating range at least once and preferably twice annually.

A full reservoir could result in large outlet discharges so it is recommended that gate cycling be scheduled during periods of low storage or low stream flows. If large releases are anticipated, coordinate this with the dam safety officer, and notify downstream residents, water users located downstream and the local fisheries officer.

NOTE: You should not have to use excessive force to raise or lower the gate because this can irreversibly bind the gate or damage the outlet works. Most hoisting mechanisms are designed to operate with a maximum force of 40 pounds on the operating handle or wheel. If excessive force is needed, this may mean there are problems with the outlet installation, which are causing binding in the mechanical system.

6 Identifying and Solving Problems – A Self-Help Guide

6.1 Deficiency Checklist

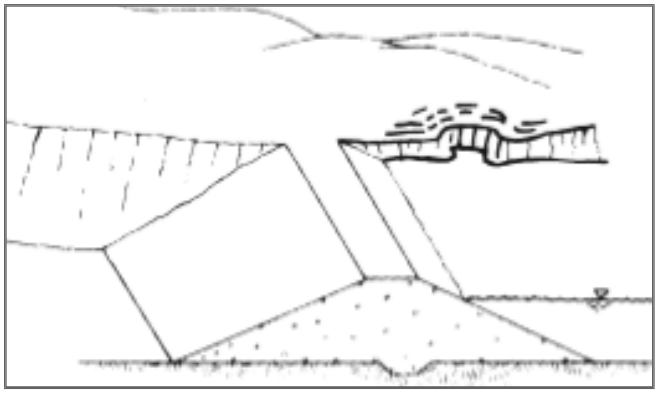
If you find deficiencies with any component of your dam, use the following table to guide you to the relevant section of this self-help section.

IS/ARE THERE ANY APPARENT	YES	NO	IF YES, THEN
CRACKS			
Embankment cracks on the crest?			Section 6.3
Embankment cracks on the upstream slope?			Section 6.4
Embankment cracks on the downstream slope?			Section 6.5
VEGETATION GROWTH AND DEBRIS			
Excessive vegetation growth on embankments/crest?			Section 6.3, 6.4, 6.9
Floating debris?			Section 6.2
Vegetation or debris blocking the spillway channel?			
STRUCTURAL PROBLEMS			
Settlement on the crest?			Sections 6.3, 6.4
Slough, slides or bulges on the upstream slope?			Section 6.4
Slough, slides or bulges on the downstream slope?			Section 6.5
Slough, slides or bulges on the reservoir shore?			Section 6.2
Slough, slide or erosion of spillway channel?			Section 6.9
Sinkhole on crest?			Section 6.3
Sinkhole on the upstream slope?			Section 6.4
Collapse on the downstream slope?			Section 6.5
Displaced or broken-down riprap armour?			Section 6.4
SEEPAGE			
Wet areas or seepage on downstream slope or toe?			Section 6.5
Ponded water at the downstream toe?			Section 6.6
Wet areas or seepage along downstream abutments?			Section 6.7
ANIMAL ACTIVITY			
Signs of livestock traffic across dam embankment?			Section 6.3
Rodent burrows in dam embankment?			Sections 6.3, 6.4
Beaver dams in reservoir or across spillway channel?			Section 6.2
OUTLET PROBLEMS			
Outlet operating problems?			Section 6.7
Deterioration of the outlet conduit?			Section 6.7
Hole in conduit?			Section 6.7
SPILLWAY PROBLEMS			
Spillway blockage?			Section 6.9
Channel blockage?			Section 6.9
Inadequate capacity?			Section 6.9

6.2 Reservoir Problems

Debris and slides are the biggest risks for reservoirs – and since they are artificial water bodies, there could be saturation issues when land that was once dry is covered with water.

SLIDES AND SLOUGHS

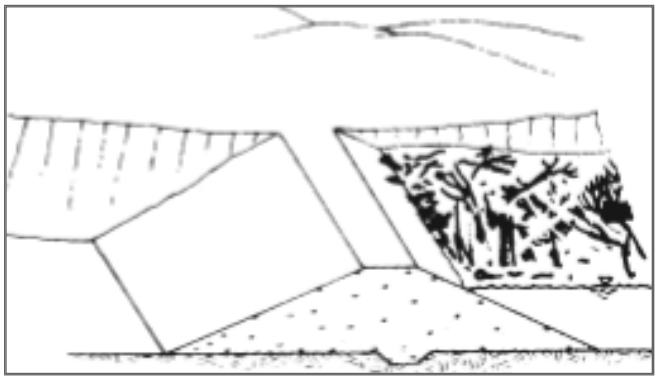


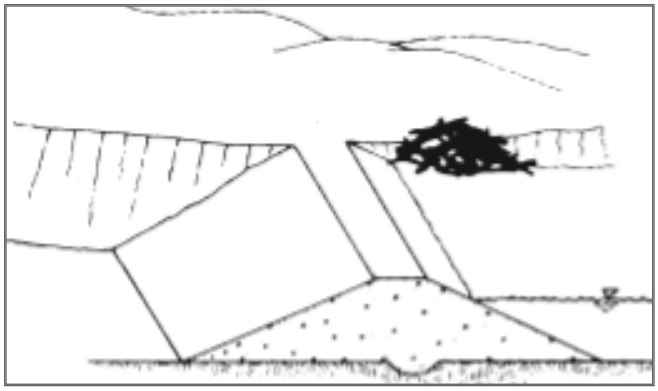
Ice action and waves can create steep reservoir side-slopes, which in turn can lead to erosion and slides, creating waves that endanger the embankment. This can also occur if the toe of a side-slope becomes saturated by the reservoir.

ACTIONS:

- Monitor the reservoir, and notify the dam safety officer if the embankment is threatened. The services of a qualified professional engineering consultant may be needed.

FLOATING DEBRIS/BEAVER ACTIVITY





Floating debris resulting from animal activity or heavy runoff can block the outlet or spillway or outlet. Properly designed trash racks stop larger debris while allowing the passage of leaves, twigs and other smaller debris.

ACTIONS:

- Install trash racks or floating log booms, and clean them as necessary.
- Ask the dam safety officer for information about rodent control. Contact FrontCounter BC for permit information.

6.3 Crest Problems

Dam crests are safest when they are clear of unwanted vegetation so potential issues such as ruts and cracks can be seen and repaired promptly. Some problems, such as sinkholes or longitudinal/transverse cracking, can quickly turn into a serious problem that could risk dam failure.

EXCESSIVE VEGETATION

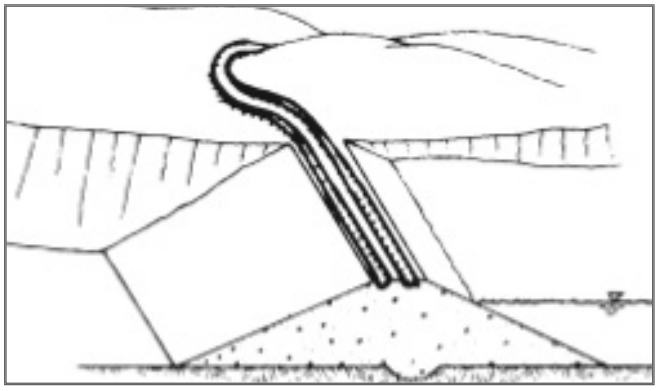
Excessive vegetation on the crest can obscure the view of the embankment and prevent a thorough inspection for possible cracks or evidence of other problems. Trees uprooted by storms can create a large hole, which could lead to dam failure. Root systems can cause concrete slabs or structures to lift or can decay and rot, leading to internal erosion/piping.

Unwanted vegetation can attract burrowing animals such as beavers or muskrats that can cause a variety of different types of damage.

ACTIONS:

- Remove woody vegetation, including the root system, as part of a regular maintenance program, and move the cuttings away from the embankment. Do not remove the root structure of woody vegetation more than three metres in height as this could affect the surface structure of the dam. You should contact a qualified professional engineer
- Use an appropriate native variety of grass to seed the embankment.
- Control animals by removing vegetation that offers favourable habitat and filling in burrows with compacted fill or pumped grout.
- Ask the dam safety officer for information about rodent control. Contact FrontCounter BC for permit information.

RUTS

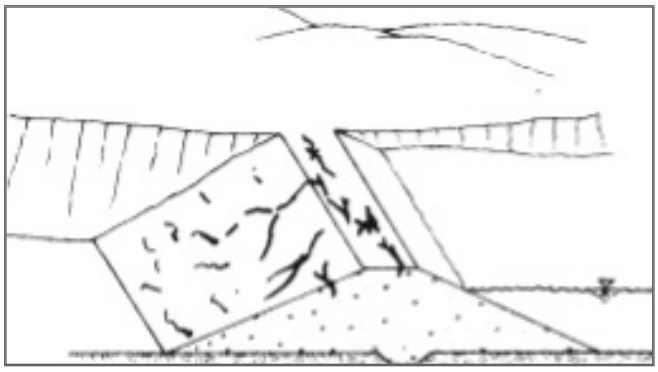


Heavy vehicles, farm equipment or livestock can cause rutting on the crest, especially if there is a lack of maintenance or inadequate crest surfacing.

ACTIONS:

- Regrade and recompact existing crest material to original elevation, sloping it to encourage the runoff to drain back into the reservoir.
- If no previous crest material was used, install a surface such as crushed gravel that can resist rutting.

DRYING CRACKS

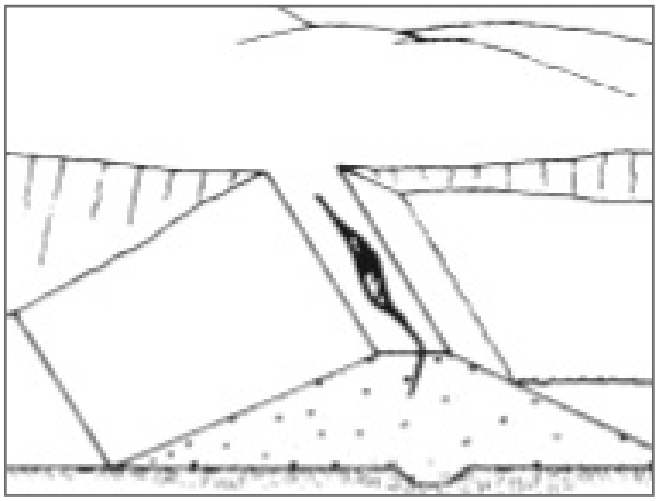


If the crest expands and contracts in wet and dry weather, it can create cracks where water can enter the crest material.

ACTION:

- Regrade or reshape the crest if necessary.

LONGITUDINAL CRACKING



Longitudinal cracking is the result of uneven settlement within the embankment or foundation. It often signals the early stages of a slope failure or embankment slide. It results in an area of high instability that can lead to further movement or failure. It provides an entry point for water and reduces the effective crest width.

ACTIONS:

- Monitor the crack and consider a lower operating reservoir level if necessary.
- This can become a serious issue so you should alert the dam safety officer and may need to hire a professional engineering consultant for advice.

TRANSVERSE CRACKING

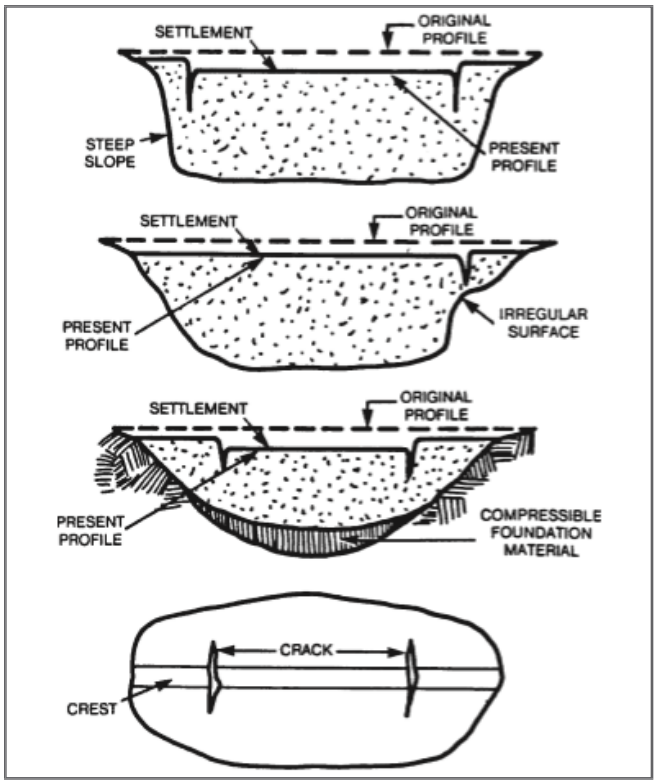
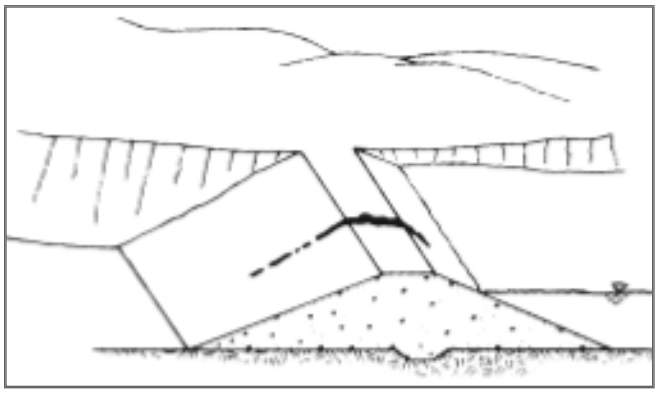


FIGURE 11: *Transverse Cracking*

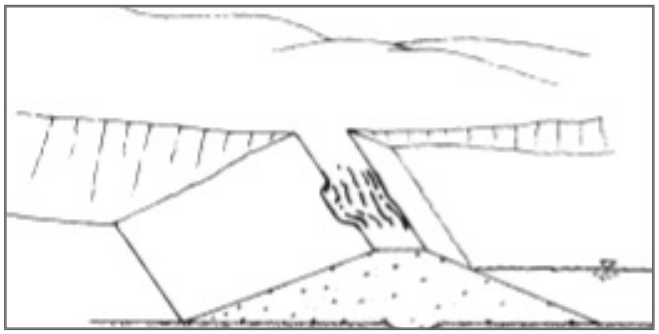


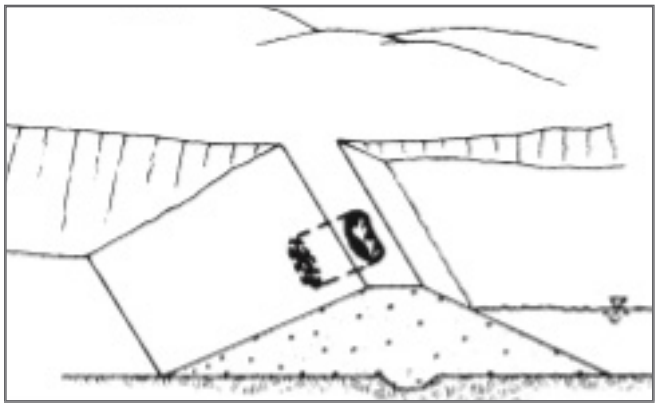
Transverse cracks can be caused by uneven movement between two adjacent segments of the embankment, or by instability of the embankment or foundation. It can provide an entry point for surface water, create an area of structural weakness, or create a seepage path from the reservoir leading to potential piping failure.

ACTIONS:

- Excavate the crack(s) and backfill with compacted material to prevent seepage.
- Monitor the area closely for future movement.
- This can become a serious issue so you could alert the dam safety officer and may need to hire a professional engineering consultant to determine the cause and recommend a plan of action.

LOW AREA OR SINKHOLES





Excessive settlement of the embankment material or foundation, internal erosion, prolonged erosion from wind or water, or poor construction techniques can result in a low area on the crest. This may result in waters overtopping the dam rather than passing through the spillway.

Burrowing animals or internal erosion from seepage piping or a hole in the conduit can cause a sinkhole that leads to embankment instability and provide an entrance point for water. Depending on the size and depth, it could cause dam failure.

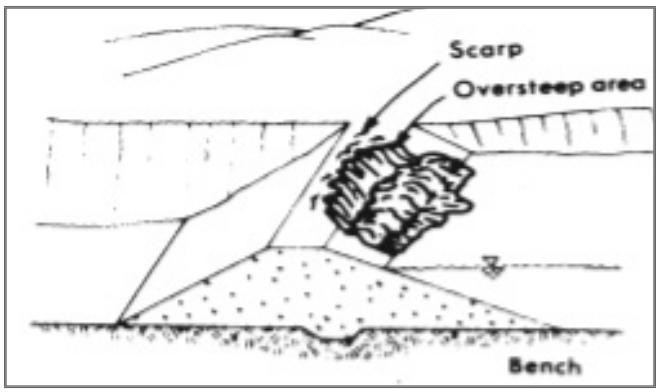
ACTION:

- Both situations could become a serious issue so you should alert the dam safety officer and may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

6.4 Upstream Slope Problems

As long as the side of the dam that is in contact with the reservoir is properly protected it can stand up to waves or ice action that could cause erosion. Some problems, such as cracks or sinkholes, can quickly turn into a serious problem that could risk dam failure.

EROSION

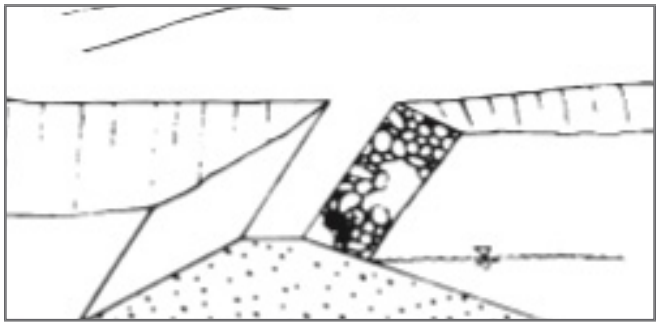


Wave action, local settlement or inadequate erosion protection can result in erosion that could reduce the crest width and height, leading to overtopping, or cause increased seepage.

ACTIONS:

- Regrade the upstream slope to the original design grade.
- Provide adequate slope protection as specified by a qualified professional

DISPLACED/BROKEN DOWN RIPRAP

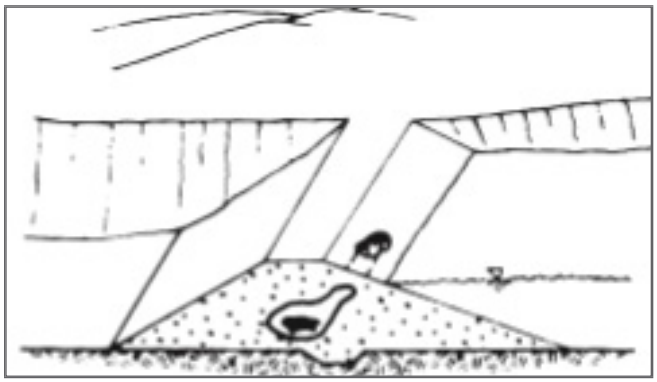


If the riprap is of poor quality or its placement is poorly designed with gaps, this could allow wave or ice action to erode the underlying material and reduce the embankment height and width.

ACTIONS:

- Re-establish adequate slope protection with underlying filter bed.
- Repair erosion damage and install properly designed erosion protection.

EXCESSIVE VEGETATION/BURROWING ANIMALS

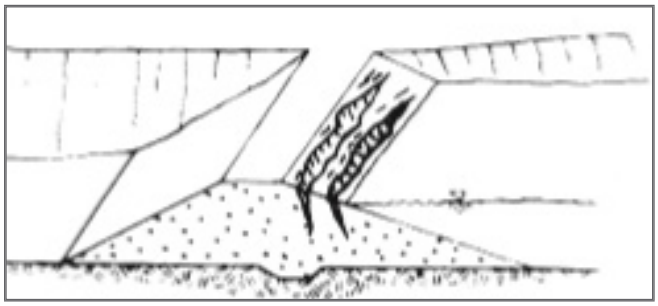


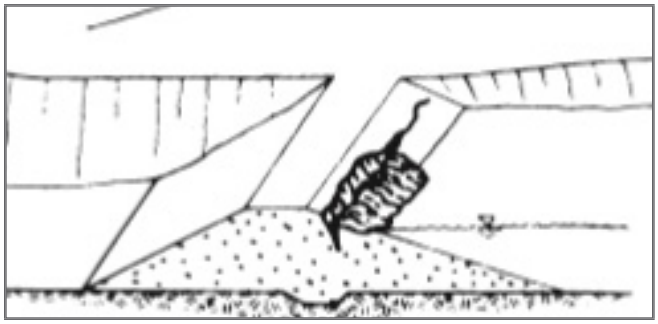
Neglect or poor maintenance can lead to excessive vegetation on the dam, which makes it hard to spot issues. Root systems can weaken the embankment and create seepage paths. Vegetation can attract beavers or muskrats, which can burrow into the dam and cause it to fail.

ACTIONS:

- Remove excessive vegetation and keep it under control as part of a routine maintenance program.
- Control animals by removing favourable habitat conditions and filling in burrows with compacted fill or pumped grout.
- Ask the dam safety officer for information about rodent control. Contact FrontCounterBC for permits.

LARGE CRACKS OR SLIDES/SLUMPS



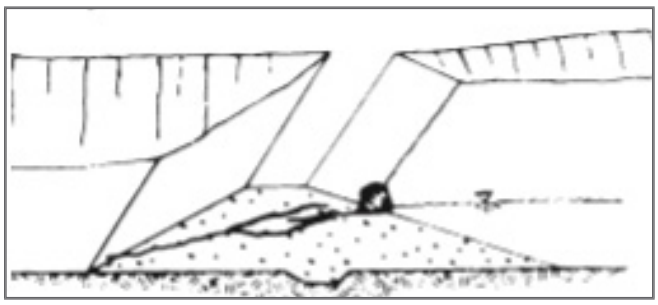


A foundation failure or localized instability almost always precedes a slope failure or large-scale settlement. A slide or slump caused by foundation failure, a slope that is too steep, or a rapid drawdown of the reservoir can lead to dam failure. Slide debris can block low-level outlets.

ACTION:

- This could become a serious issue so you should draw the reservoir down and alert the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

SINKHOLES



If concentrated seepage begins to "pipe" embankment material through the dam, it can cause the inlet of the "pipe" to collapse, forming a sinkhole. This usually results in piping failure.

ACTIONS:

- Examine the outflow for dirty water which may signal internal erosion.
- Draw the reservoir down and look for other sinkholes and their exits.
- This could become a serious issue so you should alert the dam safety officer and may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

6.5 Downstream Slope Problems

It is important to make sure the downstream slope of the dam does not show signs of cracks, slides, seepage or erosion that can lead to embankment instability.

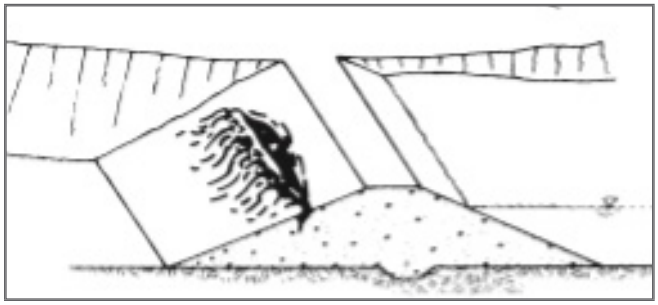
LONGITUDINAL CRACKING

If the embankment material dries or shrinks or the foundation material settles, this can lead to longitudinal cracks that provide an entry point for water or cause embankment instability. It can be an early warning of a slope failure, slide or slump.

ACTIONS:

- Seal drying cracks.
- Notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

SLUMPS/SLIDES

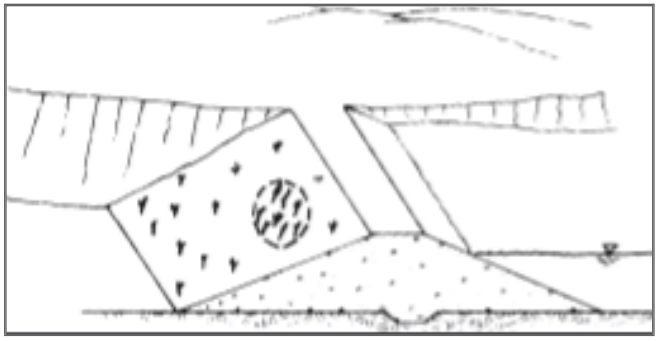


If the steep slope, settlement, or excessive seepage have led to the loss of embankment material, this can cause slumps or slides which in turn can lead to embankment failure.

ACTION:

- Draw down the reservoir.
- Notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

WET AREAS/SEEPAGE



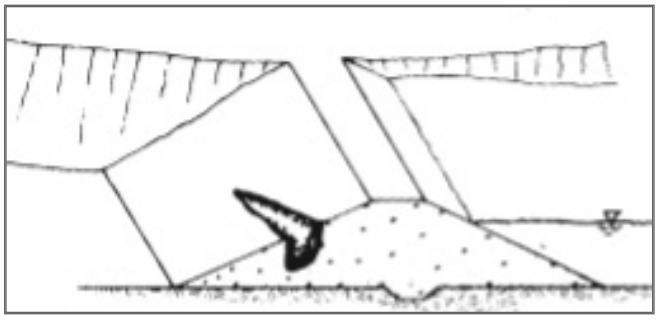
Seepage can appear as a soft, wet area, as standing water, or as a flowing spring. It can emerge on the dam's downstream slope, below the toe of the dam, or on the downstream abutments. Over time a change in vegetation may be observed. If the seepage is on the downstream slope, you will want to watch it closely – it can lead to slope failure.

All dams have some seepage. If the seepage is clear water, it is not usually a serious problem as long as there are adequate drains and filters so it does not affect the fill material and the water is not allowed to pond at the downstream toe. If the seepage is dirty water, this means it is eroding the fill material, and could lead to dam failure unless immediate action is taken.

ACTIONS:

- Mark the area with stakes or pegs, and monitor it to note any change in size.
- Check the seepage outflow for dirty water.
- If seepage is dirty, notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

CAVE-IN/COLLAPSE

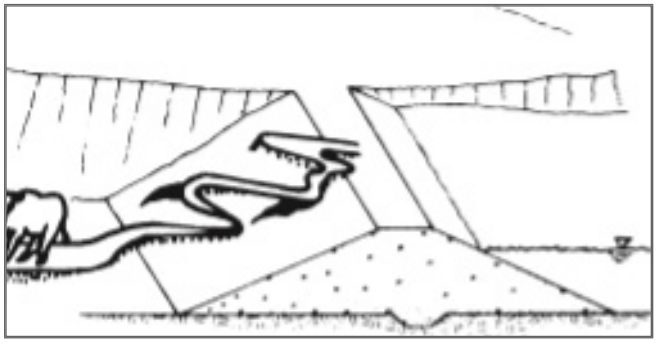


Poor compaction during construction, internal erosion through the embankment or foundation or animal burrowing can cause increased seepage leading to a cave-in or collapse that indicates the potential for failure.

ACTIONS:

- Monitor the area and note any change in size.
- Notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

EROSION/RUTTING



Livestock traffic, surface runoff and a poorly protected slope could lead to erosion or rutting.

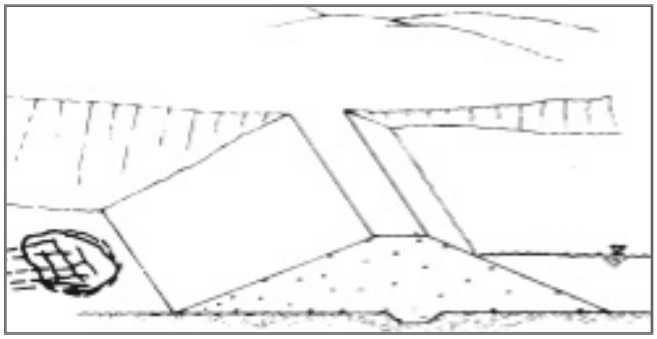
ACTIONS:

- Regrade the slope and sow a cover crop if desired.
- Keep livestock off the embankment.

6.6 Downstream Toe Problems

Watch for seepage at the junction of the downstream slope and the foundation, also known as the toe of the dam, and make sure there is adequate drainage away from the dam.

SAND OR WATER BOIL



If a concentrated seepage path or pipe has developed through the foundation or a layer of sand or gravel in the foundation is being fed by the reservoir, then the seepage water can exit as a sand or water boil.

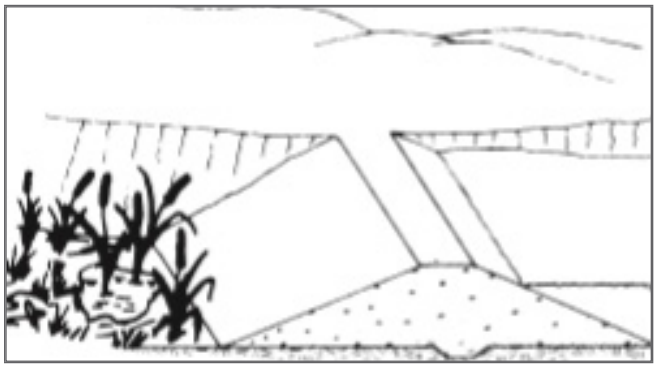
NOTE: The boil could be located five to 10 metres or more from the toe of the dam.

Dirty seepage water is an indication that piping may be occurring, and this could result in a piping failure of the foundation, and ultimately of the embankment.

ACTIONS:

- Examine the outflow for dirty water, which could signal internal erosion.
- Monitor the area and the flow more frequently, and draw down the reservoir if the flows increase.
- Notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

STANDING/PONDED WATER



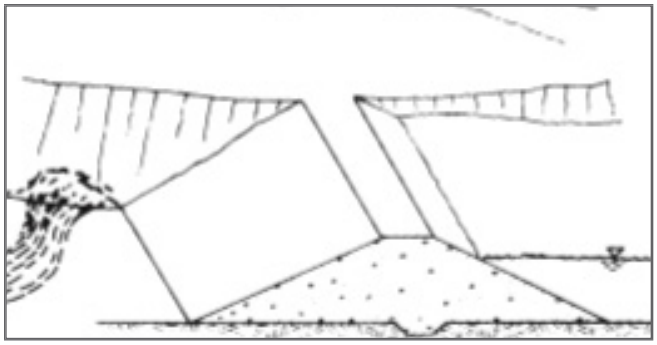
Heavy seepage, surface runoff or poor drainage from the toe can lead to standing or ponded water at the downstream toe. The water obscures the source and makes it hard to estimate flow rates. It can also saturate and destabilize the downstream slope, and this can lead to slope failure.

ACTIONS:

- Provide an adequate drainage system to prevent ponding.
- Identify the source of water, and consult a professional engineer if necessary.

6.7 Downstream Abutment Problems

WET AREAS OR WATER EXITING



A seepage path or "pipe" passing around the embankment through the natural abutment material can result in an abutment piping failure. If the water is dirty, this can indicate potential for failure of the natural abutment.

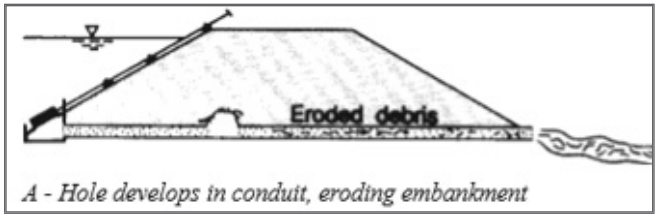
ACTIONS:

- Monitor the area and flow for change and the presence of dirty water.
- Notify the dam safety officer. You may need to bring in a professional engineering consultant if the seepage flow increases and dirty water is present.

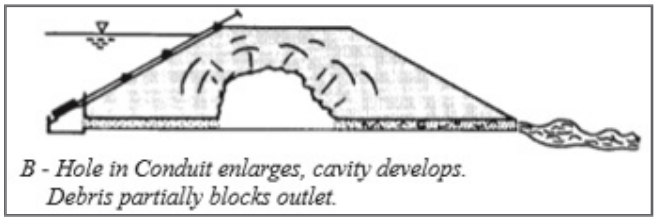
6.8 Low Level Outlet Problems

Regular maintenance is important to keep the control system operating properly and avoid problems related to the conduit, which allows for the controlled release of water from the reservoir.

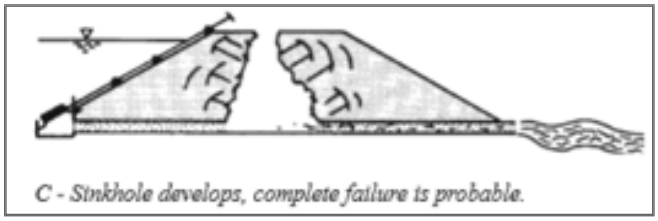
HOLE IN CONDUIT



A - Hole develops in conduit, eroding embankment



B - Hole in Conduit enlarges, cavity develops. Debris partially blocks outlet.



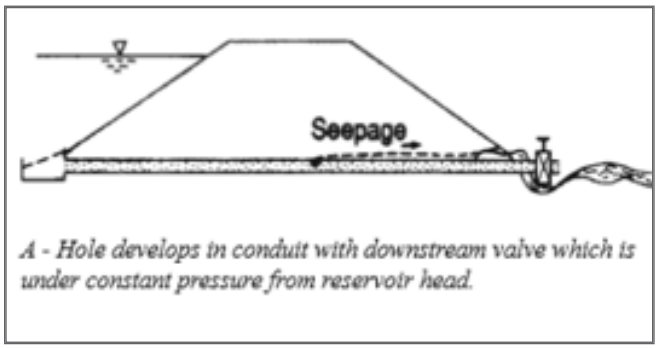
C - Sinkhole develops, complete failure is probable.

If a hole develops in the conduit, it could erode the embankment. If this is not dealt with promptly, it could get larger, and debris could partially block the outlet. If a sinkhole develops, this likely will lead to dam failure.

ACTIONS:

- This is a serious deficiency so you must notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

HOLE IN CONDUIT: DOWNSTREAM VALVE



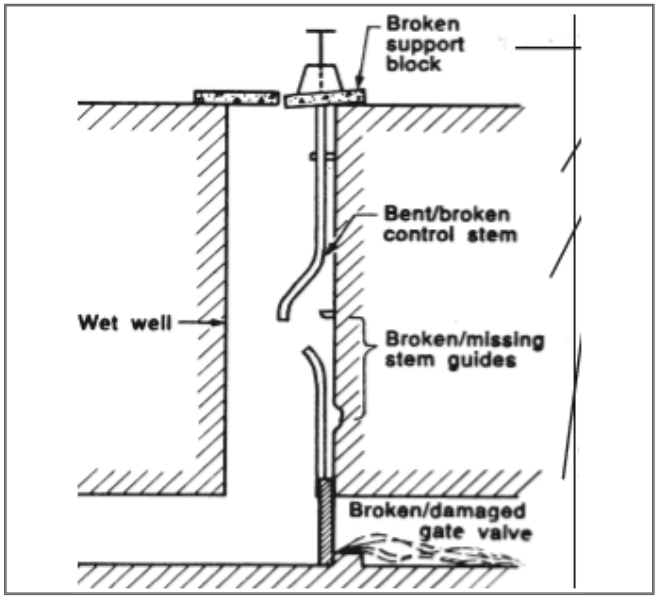
A - Hole develops in conduit with downstream valve which is under constant pressure from reservoir head.

Downstream valves are not an acceptable dam safety practice because they put the outlet under constant pressure. If an existing dam has a downstream valve, and a hole develops in the conduit, piping erosion will likely occur. If this is allowed to continue, it could very easily result in a slumping failure of the embankment.

ACTIONS:

- This is a serious deficiency so you must notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

INOPERABLE LOW LEVEL OUTLET CONTROL

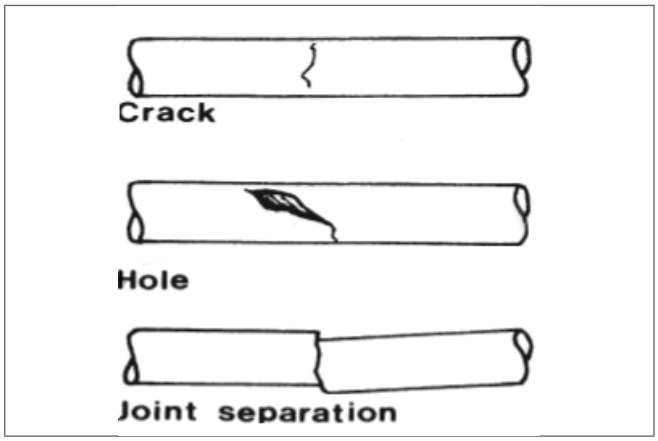


Regular maintenance is important to keep the control system operating properly. For example, broken or deteriorated concrete in the outlet can place excessive force on a jammed control stem; inadequate or broken stem guides can require excessive pressure to operate the gate; the guides can bind to the stem and break when the gate is jammed; or there can be corrosion, cavitation or impacts from water-borne debris. Any of these issues could result in inoperable gate control, preventing a drawdown of the reservoir when required, and preventing passage of water for downstream use. If the gate cannot be closed completely, reservoir operating levels cannot be maintained and water is wasted.

ACTIONS:

- Minimize the use of the outlet control until all damaged components are repaired.
- If gate cannot be operated, you should consider having a pump and hose available to lower the reservoir if water level threatens to overtop the dam
- Institute a regular maintenance program to ensure the control system is fully operable.

CORRODED OR DAMAGED CONDUIT



Corrosion or joint separation can lead to a perforated conduit, and this can lead to serious internal erosion and possible piping failure.

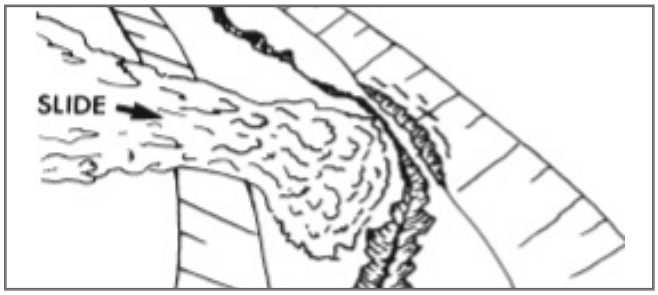
ACTIONS:

- Notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

6.9 Spillway Problems

A properly designed and maintained spillway is able to handle infrequent rain storms that may raise the level of the reservoir above its designed full supply level, and still allow waves on the upstream slope without overtopping the dam, which is the main cause of embankment dam failure.

SPILLWAY DETERIORATION



During periods of large runoff, the spillway must be able to pass a large amount of water for the duration of increased flow. This is usually not a concern if the spillway is excavated through rock or lined with concrete. But if it is excavated in sandy soils, deteriorated granite, clay or silt deposits, it needs to be protected from erosion. This can be done by ensuring the spillway channel has a mild slope, covering it with grass, or armouring it with riprap. If a channel is eroded, it can deepen and work its way upstream, and the reservoir could drain through the eroded channel.

A spillway must be maintained in order to pass the amount of flow for which it was designed. Dam owners must monitor the spillway to confirm that no barriers have developed which may impede flow. This includes the collapse of side slopes, weathering of material, disintegration of riprap, breakdown of concrete lining, erosion of the approach section, sloughing of the chute channel, excessive siltation in the stilling basin or discharge channel, and loss of protective material which can cause severe erosion. Remedial actions must be taken as soon as any sign of deterioration has been detected.

If cracks in the spillway channel caused by uneven foundation settlement, slab displacement, or excessive earth or water pressure are large enough, they allow water to wash out fine materials below or behind the concrete slab, causing erosion and more cracks, and even displacing the slab so it may be dislodged and washed away by the flow.

ACTIONS:

- Repair the eroded area with compacted fill.
- Provide adequate erosion protection, with riprap or grass.
- Regrade the channel if necessary.
- Notify the dam safety officer. You may need to bring in a professional engineering consultant to determine the cause and recommend a plan of action.

SPILLWAY OBSTRUCTIONS

If the spillway is obstructed by vegetation, floating debris, beaver dams, snowdrifts or landslide deposits, the capacity can be substantially reduced. If the channel is restricted, it can cause the reservoir to overtop the dam.

ACTIONS:

- Inspect the spillway regularly and remove any blockages.
- Remove tall weeds and brush periodically, and trees as soon as they are noticed.
- Remove any substantial amount of material deposited in the spillway channel from sloughing, landslides or sediment transport into the area.
- Stabilize slopes above a spillway channel to prevent future landslides.
- Clear debris from log booms periodically – if it becomes excessive, the log boom could break and the debris could obscure the spillway.
- Prevent future blockages by installing trash racks if necessary.
- If you are uncertain about a specific problem, consult a professional engineer.

7 More Information

There is excellent information about dam safety on the internet, and dam owners are encouraged to search for specific articles that may help them or be of interest. Here are several useful sites:

The B.C. Dam Safety website provides links to technical resources and regulations, as well as contact and training information.
www.gov.bc.ca/damsafety

The B.C. *Dam Safety Regulation* (updated 2016) sets requirements and best practices for all aspects of dam design, construction, operation, maintenance, removal and decommissioning.
www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/dam-safety-regulation

Information Sheet: Application of *Dam Safety Regulation*. *www2.gov.bc.ca/assets/gov/environment/air-land-water/water/dam-safety/2018_01_17_-_dsregulation_info_sheet_-_final.pdf*

Dam Inspection and Maintenance training courses are conducted periodically by the BC Water and Waste Association (*www.bcwwa.org/operator-education.html*) and the *Water Supply Association of BC (www.wsabc.ca/)*. For more information on dam safety training, contact the B.C. Dam Safety Program by email *dam.safety@gov.bc.ca* or by phone at 250 952-6790.

The U.S. Association of State Dam Safety Officials has posted Resources for Dam Owners and Operators at *https://damsafety.org/dam-owners*

Emergency Management BC is the province's lead coordinating agency for all emergency management activities, including planning, training, testing and exercising, to help strengthen provincial preparedness.
www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery

FrontCounter BC provides a single point of contact service to assist with permits related to natural resources, including wildlife control permits.
www.frontcounterbc.gov.bc.ca

8 Appendices

APPENDIX 1: DAM SAFETY CONTACTS

CONTACT INFORMATION
Province of BC Dam Safety Staff

FOR GENERAL INQUIRIES RELATED TO DAM SAFETY, PLEASE EMAIL: DAM.SAFETY@GOV.BC.CA

MINISTRY OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT (FLNR)
DAM SAFETY SECTION (responsible for dams 9 metres and greater in height)

	EMAIL	TELEPHONE	FAX
FOR INQUIRIES REQUIRING ASSISTANCE			
Linda Siperka Project Assistant FLNR Water Management Branch PO Box 9340 Stn Prov Govt Victoria BC V8W 9M1	Linda.Siperka@gov.bc.ca	778 698-7344	250 356-0605
MANAGEMENT			
Ted White Director/Comptroller of Water Rights, FLNR Water Management Branch PO Box 9340 Stn Prov Govt Victoria BC V8W 9M1	Ted.White@gov.bc.ca	778 698-3981	250 356-0605
DAM SAFETY SECTION			
Scott Morgan Head, Dam Safety Section FLNR Water Management Branch PO Box 9340 Stn Prov Govt Victoria BC V8W 9M1	Scott.Morgan@gov.bc.ca	250 387-3265	250 356-0605
Monty Miedreich Senior Dam Safety Officer, Dam Safety Section FLNR Water Management Branch PO Box 9340 Stn Prov Govt Victoria BC V8W 9M1	Monty.Miedreich@gov.bc.ca	250 387-3264	250 356-0605
Robert McLean, P.Eng. Senior Dam Safety Engineer, Dam Safety Section FLNR Water Management Branch PO Box 9340 Stn Prov Govt Victoria BC V8W 9M1	Robert.McLean@gov.bc.ca	250 952-6805	250 356-0605
Kevin Chan Training Coordinator, Dam Safety Section FLNR Water Management Branch PO Box 9340 Stn Prov Govt Victoria BC V8W 9M1	Kevin.2.Chan@gov.bc.ca	778 698-9091	250 356-0605
Kevin Lee Dam Safety Resource Specialist, Dam Safety Section FLNR Water Management Branch Unit 200 10428 153rd Street Surrey BC V3R 1E1	Kevin.Lee@gov.bc.ca	604 586-4442	604 586-4434

MINISTRY OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT (FLNR)
REGIONAL OPERATIONS (responsible for dams less than 9 metres in height)

WEST COAST			
John Baldwin *(Primary Contact)* Dam Safety Officer FLNR Water Protection 2080A Labieux Road Nanaimo BC V9T 6J9	John.Baldwin@gov.bc.ca	250 751-3179	250 751-7224
Dave Skarbo Dam Safety Officer/Authorizations Specialist - Water Water Authorizations Group 2100 Labieux Road Nanaimo BC V9T 6J9	David.Skarbo@gov.bc.ca	250 751-7311	250 751-7192
CARIBOO			
Dave Weir Section Head WSD Cariboo FLNR Water Stewardship Suite 400 - 640 Borland Street Williams Lake V2G 4T1	David.J.Weir@gov.bc.ca	250 267-5925	250 398-4214

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CONTACT INFORMATION
Province of BC Dam Safety Staff

	EMAIL	TELEPHONE	FAX
SOUTH COAST			
Binod Acharya, P. Eng *(Primary Contact)* Dam Safety Engineer FLNR Flood Safety Section Unit 200 10428 153rd Street Surrey BC V3R 1E1	Binod.Acharya@gov.bc.ca	778 572-2183	604 586-4434
Aman Ullah, P. Eng Dam Safety Officer/Water Power Engineer FLNR Surface Water Authorizations Unit 200 10428 153rd Street Surrey BC V3R 1E1	Aman.Ullah@gov.bc.ca	778 572-2259	604 586-4434
THOMPSON			
Darren Bennett Senior Regional Dam Safety Officer FLNR Regional Water Management, 1259 Dalhousie Drive Kamloops BC V2E 2T5	Darren.Bennett@gov.bc.ca	250 371-6329	250 828-4000
OKANAGAN			
Mike Noseworthy, P.Geo., Eng.L. Senior Dam Safety Engineer/Deputy Inspector of Dikes FLNR Regional Water Management, 102 Industrial Place Penticton BC V2A 7C8	Mike.Noseworthy@gov.bc.ca	250 490-2291	250 490-2231
KOOTENAY/BOUNDARY			
Kate Forbes, P. Ag Dam Safety Officer/Deputy Inspector of Dikes FLNR Regional Operations, 401-333 Victoria Street Nelson, BC V1L 4K3	Kate.Forbes@gov.bc.ca	250 354 6686	250 354-6332
SKEENA, OMINECA & NORTHEAST			
Michael Trudell, P.Eng. Senior Dam Safety Officer FLNR Water Stewardship, 5th Floor – 499 George Street Prince George BC V2L 1R5	Michael.Trudell@gov.bc.ca	250 561-3442	250 561-3476
Aaron Mackay, P. Ag Dam Safety Officer FLNR Water Stewardship 10003 110th Avenue Fort St. John BC V1J 6M7	Aaron.Mackay@gov.bc.ca	250 261-5785	250 261-2084
BC OIL AND GAS COMMISSION (OGC) (responsible for water supply dams for all oil and gas producers)			
Justin Anderson *(Primary Contact)* Dam Safety Officer/Authorizations Manager OGC Permit Adjudication, Southeast 6534 Airport Road Fort St. John BC V1J 1M6	Justin.Anderson@bcogc.ca	250 794-5243	250-794-5379
Dung Nguyen, P. Eng Dam Safety & Integrity Engineer #203 - 1500 Hardy Street Kelowna BC V1Y 8H2	Dung.Nguyen@BCOGC.ca	250 980-6057	250 980-6053
Gouri Bhuyan, Ph.D., P.Eng., FASME, FCAE Supervisor, Integrity Management & Dam Safety #203 - 1500 Hardy Street Kelowna BC V1Y 8H2	Gouri.Bhuyan@BCOGC.ca	250 980-6059	250 980-6053
Ken McLean, RFT Compliance and Enforcement Officer 6534 Airport Road Fort St. John, BC V1J 4M6	Ken.McLean@BCOGC.ca	250 794-5312	250-794-5390

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SCHEDULE 1

Dam failure consequences classification	Population at risk	Consequences of failure		
		Loss of life	Environmental and cultural values	Infrastructure and economics
low	none[1]	no possibility of loss of life other than through unforeseeable misadventure	minimal short-term loss or deterioration and no long-term loss or deterioration of (a) fisheries habitat or wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value	minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone
significant	temporary only[2]	low potential for multiple loss of life	no significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is highly possible	low economic losses affecting limited infrastructure and residential buildings, public transportation or services or commercial facilities, or some destruction of or damage to locations used occasionally and irregularly for temporary purposes
high	permanent[3]	10 or fewer	significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is highly possible	high economic losses affecting infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to scattered residential buildings
very high	permanent[3]	100 or fewer	significant loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is possible but impractical	very high economic losses affecting important infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas
extreme	permanent[3]	more than 100	major loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is impossible.	extremely high economic losses affecting critical infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas

SCHEDULE 2

	Activity	Frequency of Activity				
		Extreme classification	**Very high classification**	**High classification**	**Significant classification**	**Low classification**
Requirements under Part 2						
1	redetermine classification of dam and, if necessary submit to DSO written notice of proposed new classification	annually	annually	annually	annually	annually
Requirements under Part 3						
2	conduct site surveillance	weekly unless otherwise specified in the OMS manual	weekly unless otherwise specified in the OMS manual	weekly unless otherwise specified in the OMS manual	monthly unless otherwise specified in the OMS manual	quarterly
3	conduct formal inspection	semi-annually	annually	annually	annually	annually
4	test operation of (a) mechanical components of dam, and (b) electrical and communication equipment	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually
5	collect readings from instrumentation and analyze and interpret the readings	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	if and when required by a dam safety officer
6	review contact information in DEP, revise if necessary and report to DSO	annually	annually	annually	annually	not applicable
7	review emergency contact information and, if necessary, revise and submit revision to DSO	not applicable	not applicable	not applicable	not applicable	annually
8	review OMS manual and DEP, revise if necessary and report to DSO	every 7 years	every 7 years	every 10 years	every 10 years	not applicable
9	ensure dam safety review carried out and submit report to DSO	every 7 years	every 10 years	every 10 years	not applicable	not applicable

SITE SURVEILLANCE
(For Dams with Earth or Rock Embankments)

It is recommended that you customize this form for your dam

Dam Name: _____ Dam File #: _____

Inspection Date: _____ Frequency of Inspections: _____

Your Name: _____ Other Participants: _____

Was the spillway flowing? If yes, what was the water depth over the spillway sill? _____

Y ***N*** (circle one) If no, how far was the water below the spillway sill level? _____

Was the low level outlet open? If yes, what was the approximate discharge rate? _____

Y ***N*** (circle one)

Are the following components of your dam in *SATISFACTORY CONDITION*? Yes or No?

Check box if applicable - Please refer to the Inspection and Maintenance of Dams manual for dam inspection information

EMBANKMENT	Y	N
1. U/S Slope	☐	☐
2. Crest	☐	☐
3. D/S Slope	☐	☐
4. D/S Toe	☐	☐
5. Seepage Weirs	☐	☐
6. Public safety signs	☐	☐

OUTLET	Y	N
1. Outlet Pipe	☐	☐
2. Energy Dissipater	☐	☐
3. Stilling Basin	☐	☐
4. Drains	☐	☐
5. Outlet Channel	☐	☐
6. Measuring Weir	☐	☐
7. Outlet Controls	☐	☐
8. Gates	☐	☐

SPILLWAY	Y	N
1. Debris Boom	☐	☐
2. Entrance	☐	☐
3. Sill	☐	☐
4. Apron	☐	☐
5. Walls	☐	☐
7. Channel	☐	☐
8. Channel Slopes	☐	☐
9. Gates	☐	☐

Were any of the following *POTENTIAL PROBLEM INDICATORS* found?

INDICATOR	***EMBANKMENT***		***OUTLET***		***SPILLWAY***	
	YES	NO	YES	NO	YES	NO
a) Seepage	☐	☐	☐	☐	☐	☐
b) External Erosion	☐	☐	☐	☐	☐	☐
c) Cracks	☐	☐	☐	☐	☐	☐
d) Settlement	☐	☐	☐	☐	☐	☐
e) Sloughing / Slides	☐	☐	☐	☐	☐	☐
f) Animal Activity	☐	☐	☐	☐	☐	☐
g) Excessive Growth	☐	☐	☐	☐	☐	☐
h) Excessive Debris	☐	☐	☐	☐	☐	☐

Comment on any problems, concerns or deficiencies found:

_____

_____

_____

_____

_____

- ***Complete and file this report form weekly or as required in your OMS manual.***
- ***This form may also be used for monthly inspections of significant failure consequence dams or for quarterly inspections for low failure consequence dams (see Schedule 2 of the Dam Safety Regulation).***
- ***Documentation of your site surveillance may be requested by a Provincial Dam Safety Officer.***

Updated: September 2014

SITE SURVEILLANCE
(For Dams with Earth or Rock Embankments)

It is recommended that you customize this form for your dam

Sketch

SITE SURVEILLANCE
(For Concrete Dams)

It is recommended that you customize this form for your dam

Dam Name: _____ Dam File #: _____

Inspection Date: _____ Frequency of Inspections: _____

Your Name: _____ Other Participants: _____

Was the spillway flowing? If yes, what was the water depth over the spillway sill? _____

Y ***N*** (circle one) If no, how far was the water below the spillway sill level? _____

Was the low level outlet open? If yes, what was the approximate discharge rate? _____

Y ***N*** (circle one)

Are the following components of your dam in *SATISFACTORY CONDITION*? Yes or No?

Check box if applicable - Please refer to the Inspection and Maintenance of Dams manual for dam inspection information

CONCRETE STRUCTURE	Y	N
1. Alignment	☐	☐
2. Joint Filler	☐	☐
3. Concrete Condition	☐	☐
4. Drains	☐	☐
5. Public safety signs	☐	☐

OUTLET	Y	N
1. Outlet Pipe	☐	☐
2. Energy Dissipater	☐	☐
3. Stilling Basin	☐	☐
4. Drains	☐	☐
5. Outlet Channel	☐	☐
6. Measuring Weir	☐	☐
7. Outlet Controls	☐	☐
8. Gates	☐	☐

SPILLWAY	Y	N
1. Debris Boom	☐	☐
2. Entrance	☐	☐
3. Sill	☐	☐
4. Apron	☐	☐
5. Walls	☐	☐
6. Channel	☐	☐
7. Channel Slopes	☐	☐
8. Gates	☐	☐

Were any of the following *POTENTIAL PROBLEM INDICATORS* found?

INDICATOR	***CONCRETE STRUCTURE***		***OUTLET***		***SPILLWAY***	
	YES	NO	YES	NO	YES	NO
a) Seepage	☐	☐	☐	☐	☐	☐
b) External Erosion	☐	☐	☐	☐	☐	☐
c) Cracks	☐	☐	☐	☐	☐	☐
d) Settlement	☐	☐	☐	☐	☐	☐
e) Horizontal Movement	☐	☐	☐	☐	☐	☐
f) Excessive Debris	☐	☐	☐	☐	☐	☐
g) Vegetation	☐	☐	☐	☐	☐	☐

Comment on any problems, concerns or deficiencies found:

_____

_____

_____

_____

_____

- ***Complete and file this report form weekly or as required in your OMS manual.***
- ***This form may also be used for monthly inspections of significant failure consequence dams or for quarterly inspections for low failure consequence dams (see Schedule 2 of the Dam Safety Regulation).***
- ***Documentation of your site surveillance may be requested by a Provincial Dam Safety Officer.***

Updated: September 2014

SITE SURVEILLANCE
(For Concrete Dams)

It is recommended that you customize this form for your dam

Sketch

Updated: September 2014

Ministry of Forests, Lands and Natural Resource Operations

INFORMATION SHEET

DAM SIGNAGE REQUIREMENTS FOR DAM OWNERS

SIGNAGE MANDATE

As specified in the British Columbia Dam Safety Regulation, as of November 30, 2011, all owners of dams located partially or entirely on Crown Land and that have a classification of significant, high, very high or extreme must post signs at those dams in the manner described in the Regulation. The requirement for signage on dams is a commitment that meets one of the twelve recommendations put forward by David Morhart, Deputy Solicitor General in his report entitled Review of the Testalinden Dam Failure (July 2010). Recommendation #3 states: *The Ministry of Environment* (now the Ministry of Forest, Lands & Natural Resource Operations) *should consider implementing signage to make it clear to passersby that the structure is a dam and to provide direction and emergency contact information, including contact information for the owner, to report any issues observed."*

GENERAL SIGNAGE CRITERIA AND INFORMATION FOR DAM OWNERS

1. Considerations for Signs
   - Background colour and reflectivity can affect the visibility of safety signs. Low light conditions may reduce visibility and make existing signs ineffective.
   - Use of a reflective background material can increase visibility.
   - Signs usually consist of dark lettering on light backgrounds or vice versa to ensure legibility.
   - Keeping signage consistent increases recognition by the public.
   - Where possible, sign placement should consider sun and glare, shadows, orientation and visitor safety.
   - As a general rule, place signs on the right hand side (when facing the dam crest) of the approach to the dam.
   - Sign placement should not interfere with the normal operation of the dam.
   - Sign placement should not be too close to trees or foliage that could cover the face of the sign.

2. Materials and Cost

   Dam owners are responsible for the cost, installation and maintenance of signs on their dams. Costs vary greatly with quantity, size, location and type of material used. Commonly used materials for signs are:
   - Marine quality, ¾ inch plywood,
   - Medium density Fiberboard (MDF), and
   - Aluminum.

   The post kits (post, sleeves, bolts and anchor) required will depend on the situation and sign material chosen. For installation at provincial dams, the posts chosen were 3.6 metres long and 57 mm in diameter. The anchor was 1050 mm long and 64 mm in diameter. Each post kit weighed about 23 kilograms. Installation costs vary depending on the location of the dam, type of installation required and whether installed by the dam owner or contractor.

3. Maintenance

Inspection and maintenance procedures for the signs must be included by the dam owner in the dam's Operation, Maintenance and Surveillance manual. Standard maintenance plans should address physical damage, visibility, legibility and appearance. Key concepts of a maintenance plan should include:

- Frequent inspections to ensure that signs are maintained and repaired as needed – include sign check as part of the surveillance and formal inspection of the dam and include procedures into the dam's Operation, Maintenance & Surveillance manual.
- Taking precautions to reduce vandalism to the signs,
- Repairing or replacing damaged signs quickly,
- Checking the reflectivity of signs that are meant to be seen at night, and
- Updating protocols for employees and/or visitors to report damage.

Experience suggests that annual maintenance of signs averages about 30% of the initial cost as signs are common targets for graffiti and gun shots.

4. Specifications for Signs

Signs must conform to the specifications provided in the British Columbia Dam Safety Regulation. This includes but is not limited to:

- Signs must be at least 75 centimetres high and 60 centimetres wide.
- Lettering on the sign must be clearly visible from 15 meters.
- The sign must contain the following information and be in the following format:

<DAM NAME>
<STREAM NAME>

IF YOU SEE ANY
DAM SAFETY CONCERNS,
PLEASE CONTACT:
<DAM OWNER NAME>
DAY: ___-___-____
NIGHT: ___-___-____

PROVINCIAL EMERGENCY PROGRAM

1-800-663-3456

For Example:

MORE INFORMATION

Information on dam safety is available on the BC Government Dam Safety Website:
http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/index.html

Or, can be obtained from your local Dam Safety Officer or by contacting:

Dam Safety Section
Water Management Branch
PO Box 9340 Stn Prov Govt
Victoria BC V8W9M1

Formal Annual Inspection

It is recommended that you customize this form to fit your dam.

Pre-Inspection Information

Name of Dam: _____ Inspection Date: _____
Current Weather: _____ Weather During Last Week: _____
Name of Creek, Stream, River: _____ Water Licence #: _____
Dam Owner: _____
Address: _____
City, Province: _____ Postal Code: _____
Name of Principle Contact Person: _____
Principle Contact's Bus Phone: _____ Principle Contact's Cell Phone: _____
Principle Contact's Email: _____

Person Responsible for this Inspection: _____ Phone #: _____
Other Inspection Participants: _____

Date of Last Annual Inspection: _____ Was last Annual Inspection Report reviewed?: _____
Were dam deficiences identified that required follow-up? _____
Date of Last Dam Safety Report(DSR): _____ Was last DSR Report reviewed? _____
Were recommendations from the last DSR Report implemented? _____
Repairs or modifications since last formal inspection? (where, when) _____
Failures/Incidents/Breaches since last formal inspection? _____
Has all the maintenance done in the last year been documented?_____
Are the Works Currently Fully Operational? _____

Dam Information

Type of Dam: _____ Max. Height of Dam: _____
Are dam materials well known? _____ Are foundation conditions well known? _____
Are dam construction details well known? _____ Construction Date: _____

Failure Consequence Classification

Circle current Failure Consequence Classification (based on BC Dam Safety Regulation)

Low Significant High VeryHigh Extreme

Hydrology

Drainage Area Size: _____ Reservoir Area: _____
Inflow Design Flood (IDF): _____ m^3/s IDF Return Period: _____
1000 yr Flood: _____ m^3/s (If available): _____
Probable Maximum Flood: _____ m^3/s (If available): _____
Spillway Crest Elevation: _____ Spillway Width: _____
Spillway Capacity: _____ Net Freeboard (while spillway passing IDF): _____
Gross Freeboard (@ full supply level): _____ Freeboard (at time of visit): _____
Reservoir Storage Volume: _____ Licenced Storage Volume: _____

Emergency Preparedness Plan (EPP)

Has the emergency contact information in the EPP been updated this year and distributed as required? _____

Other Key Information

Person Responsible for Formal Inspection: _____ Date: _____

	Required Action					Photo #s
	None	Monitor	Maintenance	Repair	N / A	

Embankment Dam

1. Upstream Slope

VEGETATION Yes/No ☐ ☐ ☐ ☐ ☐ _____

Type _____ Location _____

Recommendations: _____

SLOPE PROTECTION ☐ ☐ ☐ ☐ ☐ _____

Type None/Grass/Riprap/Other

Notes _____

EROSION Yes/No Location _____ ☐ ☐ ☐ ☐ ☐ _____

Type Wave/Runoff/Unknown

Length _____ Width _____

Notes _____

INSTABILITIES ☐ ☐ ☐ ☐ ☐ _____

Slides Yes/No/Could not Inspect

Length _____ Width _____ Location _____

Notes/Causes _____

Cracks Yes/No Transverse/Longitudinal/Other ☐ ☐ ☐ ☐ ☐ _____

Quantity _____ Length _____ Width _____

Location _____

Notes/Causes _____

Bulges/Depressions/Hummocky Yes/No ☐ ☐ ☐ ☐ ☐ _____

Size _____ Height _____ Depth _____

Location _____

Notes/Causes _____

OTHER ☐ ☐ ☐ ☐ ☐ _____

Burrows, Ruts, Other Concerns

Location _____

Notes/Causes _____

2. Crest

ACCESS ☐ ☐ ☐ ☐ ☐ _____

Is there public access to the crest? (Yes/No)

Is the crest marked or signed? (Yes/No)

Is vehicle access to the crest restricted? (Yes/No)

VEGETATION

Trees Yes/No ☐ ☐ ☐ ☐ ☐ _____

Location _____

Notes _____

Brush None/Sparse/Dense ☐ ☐ ☐ ☐ ☐ _____

Location _____

Notes _____

Ground Cover Bare/Grass/Other ☐ ☐ ☐ ☐ ☐ _____

Quantity (bare/sparse/adequate/dense)

Appearance (too tall/too short/good)

Notes _____

EROSION Yes/No Location _____ ☐ ☐ ☐ ☐ ☐ _____

Type Wave/Runoff/Unknown

Length _____ Width _____

Notes _____

SETTLEMENT ☐ ☐ ☐ ☐ ☐ _____

Location _____

Notes/Causes _____

	Required Action					Photo #s
	None	Monitor	Maintenance	Repair	N / A	
INSTABILITIES	☐	☐	☐	☐	☐	_____
Cracks Transverse/Longitudinal/Other						
Quantity _____ Length _____ Width _____						
Location _____						
Notes/Causes _____						
OTHER						
Burrows, Ruts, Other Concerns	☐	☐	☐	☐	☐	_____
Location _____						
Notes/Causes _____						

3. Downstream Slope

VEGETATION	☐	☐	☐	☐	☐	_____
Trees Yes/No						
Location _____						
Notes _____						
Brush None/Sparse/Dense	☐	☐	☐	☐	☐	_____
Location _____						
Notes _____						
Ground Cover Bare/Grass/Other	☐	☐	☐	☐	☐	_____
Notes _____						
SLOPE PROTECTION	☐	☐	☐	☐	☐	_____
Type None/Grass/Other						
Notes _____						
EROSION Yes/No Location _____	☐	☐	☐	☐	☐	_____
Location _____						
Notes _____						
INSTABILITIES	☐	☐	☐	☐	☐	_____
Slides Length _____ Width _____ Location _____						
Notes/Causes _____						
Cracks Yes/No Transverse/Longitudinal/Other	☐	☐	☐	☐	☐	_____
Quantity _____ Length _____ Width _____						
Location _____						
Notes/Causes _____						
Bulges/Depressions/Hummocky Yes/No	☐	☐	☐	☐	☐	_____
Size _____ Height _____ Depth _____						
Location _____						
Notes/Causes _____						
OTHER						
Burrows, Ruts, Other Concerns	☐	☐	☐	☐	☐	_____
Location _____						
Notes/Causes _____						
SEEPAGE	☐	☐	☐	☐	☐	_____
Wet Area/Flow/Boil/Sinkhole						
Flow Rate _____						
Location _____						
Aquatic Vegetation Yes/No						
Rust Colored Deposits Yes/No						
Sediment in Flow Yes/No						
Other _____						
Notes/Causes _____						
EMBANKMENT DRAINS Yes/No	☐	☐	☐	☐	☐	_____
Type _____						
Flow rate _____ Size _____ Number _____						
Location _____						
Notes _____						
MONITORING INSTRUMENTATION CONDITION	☐	☐	☐	☐	☐	_____
☐ None found ☐ Piezometers ☐ Weir ☐ Flume						
Notes _____						

	Required Action					Photo #s
	None	Monitor	Maintenance	Repair	N / A	

Concrete Dam

1. Upstream Side and Crest

ALIGNMENT/OFFSETS ☐ ☐ ☐ ☐ ☐ _____

Movement at Joints? _____

Settlement? _____

JOINT FILLER ☐ ☐ ☐ ☐ ☐ _____

Any Loss? _____

Vegetation? _____

UNUSUAL CRACKS ☐ ☐ ☐ ☐ ☐ _____

New? _____

Efflorescence? _____

Displacement? _____

DETERIORATION ☐ ☐ ☐ ☐ ☐ _____

Concrete Breakdown? _____ Diagnosis: _____

Erosion _____

Scour _____

2. Downstream Side

ALIGNMENT/OFFSETS ☐ ☐ ☐ ☐ ☐ _____

Movement at Joints? _____

Settlement? _____

JOINT FILLER ☐ ☐ ☐ ☐ ☐ _____

Any Loss? _____

Vegetation? _____

UNUSUAL CRACKS ☐ ☐ ☐ ☐ ☐ _____

New? _____ Type? _____

Efflorescence? _____

Displacement? _____

DETERIORATION ☐ ☐ ☐ ☐ ☐ _____

Concrete Breakdown? _____ Diagnosis: _____

Erosion _____

Scour _____

UNUSUAL LEAKAGE ☐ ☐ ☐ ☐ ☐ _____

Increase? _____ Clear? _____

Weir? _____ Flow Estimate? _____

DRAINS ☐ ☐ ☐ ☐ ☐ _____

Flow? _____ Calcite Build-up? _____

	Required Action					Photo #s
	None	Monitor	Maintenance	Repair	N / A	

Spillway

GENERAL CONDITIONS

Type _____ Gated? - Yes/No

Notes _____

1. Spillway Crest or Control Section

OBSTRUCTION

Debris Yes/No

Location _____

Notes _____

Vegetation None/Sparse/Dense

Location _____

Notes _____

Other (beaver activity, trash rack problems, etc.)

_____

LOG BOOM Yes/No Reguired? Yes/No

Condition: Logs _____ Connections _____ Anchors _____

Notes _____

SPILLWAY CREST MATERIALS

Condition _____

Notes _____

SPILLWAY GATES Yes/No _____ Type: _____

Condition _____

Notes _____

OTHER SPILLWAY CREST PROBLEMS

Damage _____

Location _____

Notes/Cause _____

2. Spillway Conveyance Section: Channel, Chute or Conduit

OPEN CHANNEL CROSS SECTION _____

CHANNEL OBSTRUCTION _____

SPILLWAY CONVEYANCE MATERIALS _____

OTHER SPILLWAY CONVEYANCE PROBLEMS _____

Damage _____

Location _____

Notes/Cause _____

3. Energy-Dissipating or Terminal Section

EROSION CONTROL STRUCTURE

Type Endwall/Headwall/Plunge pool/impact basin/Baffled chute/Rock lined channel/Other/None

_____

Notes _____

	Required Action					Photo #s
	None	Monitor	Maintenance	Repair	N / A	

Low Level Outlet

GENERAL

Gate Type _____ ☐ None ☐ ☐ ☐ ☐ ☐ _____

ACCESS TO VALVE/GATE Under all circumstances? Yes/No ☐ ☐ ☐ ☐ ☐ _____

☐ Not accessible ☐ from shore ☐ Walkway ☐ By boat ☐ Other

Notes _____

Walkway Condition _____

LOW LEVEL OUTLET COMPONENTS

Valve Control Device ☐ ☐ ☐ ☐ ☐ _____

☐ Yes ☐ None ☐ No Stem ☐ Damaged stem ☐ Other

Other/Notes _____

Operational under all conditions? ☐ ☐ ☐ ☐ ☐ _____

☐ Yes ☐ No ☐ Poorly

Tested Annually? Yes/No Tested as per OMS manual? Yes/No

Notes _____

Valve / Gate ☐ ☐ ☐ ☐ ☐ _____

Location _____

Condition _____

Leakage ☐ Yes ☐ No ☐ ☐ ☐ ☐ ☐ _____

Flow Rate _____

Outlet Pipe ☐ ☐ ☐ ☐ ☐ _____

☐ Metal ☐ Plastic ☐ Concrete ☐ Other _____

Diameter _____

Condition _____

Outlet Obstruction (note vegetation, sediment blockage, etc.)

Notes _____

OUTLET EROSION CONTROL STRUCTURE ☐ ☐ ☐ ☐ ☐ _____

Type _____

Concrete Condition ☐ ☐ ☐ ☐ ☐ _____

Outlet Area Seepage ☐ ☐ ☐ ☐ ☐ _____

Description _____

Flow Estimate _____

Location _____

Undermining ☐ ☐ ☐ ☐ ☐ _____

Location _____

Notes/Cause: _____

Downstream Channel ☐ ☐ ☐ ☐ ☐ _____

Free Draining? _____

Blockages or Potential Blockages? _____

Erosion Control? Rip-Rap? _____

	Required Action				Photo #s
None	Monitor	Maintenance	Repair	N / A	

Other Key Information

Is site access adequate for safe operation, maintenance and surveillance? _____
Instrumentation adequate for site conditions? _____
Are there concerns about reservoir slope stability? _____
Any there other concerns in the watershed that could impact the dam? _____
Operational Constraints that impact Dam Safety? _____
Are the required Public Safety signs in place (for dams on Crown land)? _____
Other comments on Public Safety: _____
Should new development in the downstream inundation zone initiate a review of the Failure Consequence Classification?:
Yes/no? _____Comments: _____

Maintenance

In the last year have the spillway gates been exercised and tested in accordance with the OMS? _____
If so, when and by whom? _____
In the last year has the low level outlet gate been exercised and tested in accordance with the OMS? _____
If so, when and by whom? _____
Is the instrumentation well maintained? _____

NOTES:

	Required Action				Photo #s
None	Monitor	Maintenance	Repair	N / A	

SKETCH OF ISSUES:

Ministry of Forests, Lands and Natural Resource Operations

INFORMATION SHEET

GUIDE & TEMPLATE FOR PREPARING A DAM EMERGENCY PLAN (DEP) IN BRITISH COLUMBIA

INTRODUCTION

Emergency response procedures and emergency preparedness plans have been a recommended best dam safety management practice since 1984 in British Columbia. The previous British Columbia Dam Safety Regulation, *Water Act,* required all owners of dams with a consequence classification of significant or higher to prepare an Emergency Preparedness Plan (EPP) for their dams.

In 2016, the *Water Sustainability Act* and Dam Safety Regulation replaced the *Water Act* and British Columbia Dam Safety Regulation. The new regulation still requires owners of dams to prepare an emergency plan, now called a Dam Emergency Plan (DEP), however with some differences including what they must contain, what must be done with them, and the date by which they must be prepared and submitted for acceptance by the Dam Safety Officer.

REQUIREMENT

As per Sections 9 and 33 of the Dam Safety Regulation, *Water Sustainability Act*, an owner of a dam that has a consequence of failure classification of significant, high, very high or extreme must prepare a DEP that includes:

(i) a record describing the actions to be taken by the owner if there is an emergency at the dam, and

(ii) a record containing information for the use of the local emergency authorities for the dam for the purpose of preparing local emergency plans under the Emergency Program Act.

A *Guide & Template for Preparing a Dam Emergency Plan (DEP) in British Columbia* has been developed to assist dam owners in preparing their DEP.

CHANGES TO THE REQUIREMENTS OF AN EMERGENCY PREPAREDNESS PLAN

The new DEP is similar in part to the former EPP as it must describe the actions to be taken by the dam owner if a hazardous condition or potential safety hazard at the dam is detected. However, in addition, Section 9(1)(a)(ii) of the Regulation now requires that the DEP include a *record* containing specific information about the dam to be used by *local emergency authorities* (as defined in Part 1, Section 1(2) of the Regulation) for their local emergency plan; a plan mandated under the *Emergency Program Act*.

To prepare this record, the DEP template is designed so that several parts of the DEP can be easily separated to become the *record* described under Section 9(1)(a)(ii) of the Regulation for provision to local emergency authorities. Those portions of the DEP that make up this *record* from the template are: ***Sections 1, 2 & 4.1 and Appendix A (A-1, A-2 & A-3)***.

GUIDELINE AND TEMPLATE

The Canadian Dam Association (CDA) provides guidance on Emergency Preparedness for dam owners, local emergency authorities and communities in their Dam Safety Guidelines. As well as this, the Association of State Dam Safety Officials (ASDSO) and the National Dam Safety Review Board (NDSRB) in the United States have developed an EAP Resource Center to provide dam owners with simple and low cost tools for creating and implementing an Emergency Action Plan (EAP) at their dam(s).

The *Guide & Template for Preparing a Dam Emergency Plan (DEP) in British Columbia* has been adapted from the CDA guidelines and ASDSO EAP

Resource Center for use by dam owners in British Columbia to assist in the preparation of their mandatory *Dam Emergency Plan*. The DEP template is intended for smaller to mid-sized dams but could also be adapted to larger dams.

USING THE DEP TEMPLATE

It is recognized that many dam owners currently have Emergency Preparedness Plans in place. Section 33 (*Transition – Dam Emergency Plan)* of the Regulation outlines the date of the next review of this document and when changes, if any, must be submitted to the Dam Safety Officer for acceptance. Existing EPP's may be acceptable as long as the Regulation requirement outlined in section 9(1)(a)(ii) is fulfilled. For owners of previously unregulated dams, Section 33(1) of the Regulation provides timelines for submission of the DEP.

As every dam owner and their dam are unique, so are DEPs. Therefore the DEP template may be modified to reflect your dam's requirements. The DEP template is only a suggested model of an acceptable DEP and there is no requirement to follow it as long as the information contained in the DEP is acceptable to the Dam Safety Officer (Section 9(1)(b)).

WHAT TO DO ONCE DEP HAS BEEN COMPLETED

Once the dam owner has completed the DEP, the DEP needs to be forwarded to the Dam Safety Officer for acceptance. The Dam Safety Officer may return the DEP to the owner with suggestions for improvement if not satisfied with the DEP. Once accepted by the Dam Safety Officer, and as per Section 9(10) of the Regulation, the dam owner must then forward relevant sections of the DEP to the local emergency authority for the purpose of the local emergency authority's preparation of their own local emergency plans under the *Emergency Program Act*. Once again, those portions of the DEP that make up this *record* from the template are: ***Sections 1, 2 & 4.1 and Appendix A (A-1, A-2 & A-3)***.

MORE INFORMATION

More information on the DEP can be obtained by contacting:

Dam Safety Section
Water Management Branch
PO Box 9340 Stn Prov Govt
Victoria BC V8W 9M1

Email: dam.safety@gov.bc.ca

Or through the provincial dam safety website at: www.gov.bc.ca/water

Additional information on dam emergency preparedness can be found in the Canadian Dam Associations' *Dam Safety Guidelines* and website at: www.cda.ca/

Last Update: June 24, 2016

OPERATION, MAINTENANCE & SURVEILLANCE PLAN

*Dam Name:*_____ *Water Licence No.:*_____

*Owner's Name:*_____ *Phone #:*_____

*Stream Name:*_____ *Reservoir Name:*_____

Dam Location: ***Latitude:***_____ ***Longitude:***_____ ***Map Sheet No.***____

LIST INDIVIDUALS WHO ARE RESPONSIBLE FOR:

	Name	*Title*	*Phone #*
Operation:			
Maintenance:			
Inspections:			
Instrumentation:			

PHYSICAL DESCRIPTION:

*Dam Height:*_____ *Dam Type:*_____

*Length:*_____ *Crest Width:*_____

*Reservoir Capacity:*_____ *Reservoir Area:*_____

*Spillway Capacity:*_____ *Design Flood Inflow:*_____

*Watershed Area:*_____ *Purpose of Dam:*_____

*Consequence Classification:*_____

ACCESS TO DAM: *(describe road access to dam from nearest center, attach map to this Plan)*

_____

_____

_____

_____

_____

LIST SIGNIFICANT STRUCTURES DOWNSTREAM OF DAM: *(i.e., access road, railroad, subdivision etc.)*

_____

_____

_____

_____

_____

_____

LIST ALL HYDRAULIC WORKS: *(i.e., spillway, outlet, stoplogs, gates, valves etc. (include capacity, dimensions, locations etc.))*

LIST PROCEDURES FOR RESERVOIR OPERATION: *(i.e., how is reservoir level controlled? what is the anticipated reservoir level for any given time of year? when are the drawdown and filling periods? what are the operation procedures during floods?)*

LIST ALL ITEMS REQUIRING ROUTINE MAINTENANCE: *(include type of maintenance to be performed, scheduling of maintenance, record keeping, etc.)*

LIST ALL INSTRUMENTATION, FREQUENCY OF MONITORING, AND METHOD OF RECORD KEEPING: *(i.e., seepage measurement weir, reservoir level gauge, piezometers, etc.)*

LIST OF EQUIPMENT TO BE PERIODICALLY TEST OPERATED: *(i.e., gates, valves, hoists, etc. include frequency of test operation)*

LIST ALL COMPONENTS REQUIRING ROUTINE VISUAL INSPECTIONS: *(include schedule) (e.g. weekly, monthly, quarterly, annually etc.)*

ANNUAL FORMAL INSPECTIONS BY OWNER: *(include; time of year when performed, special items to be examined, reviewed, and/or test operated)*

_____

_____

_____

_____

_____

_____

_____

_____

ATTACH THE FOLLOWING INFORMATION TO THIS PLAN:

- *All dam design plans including as-built, if available.*
- *A location map showing the dam location relative to major roads and/or communities.*
- *All past inspection reports.*
- *An inspection checklist.*
- *A log showing repairs done and operating problems.*

Appendix 10: Glossary of Terms

ABUTMENT: The part of the valley side against which the dam is constructed. Left and right abutments are defined with the observer viewing the dam when looking downstream.

ALTERATIONS: A change to the existing authorized use and operation of the dam which requires the owner to obtain a specific authority under Section 12 of the Dam Safety Regulation.

APPURTENANCES: Supplementary or ancillary features of a dam such as outlets, spillways, power plants and all critical water control and release facilities. Includes mechanical and electrical control and stand-by power supply equipment located in the powerhouse or in remote control centres.

BASE OF DAM: The general foundation area of the lowest portion of the main body of a dam.

BERM: A narrow shelf or ledge on the downstream slope of the dam that controls erosion by reducing the rate of surface runoff. Sometimes constructed to add stability to the dam or increase the length of the seepage path.

BREACH OF DAM (UNCONTROLLED): An opening through a dam that allows uncontrolled draining of a reservoir.

COMPTROLLER: A person employed by government and designated in writing by the minister as the Comptroller of Water Rights, including acting, deputy or assistant comptrollers.

CONSEQUENCES OF DAM FAILURE: Downstream and upstream impacts resulting from failure of the dam or its appurtenances. Schedule 1 of the Dam Safety Regulation provides information on how to determine a dam failure consequences classification.

CONDUIT: A closed channel to convey water through, around, or under a dam.

CREST OF DAM: The upper limit of a dam, not taking into account any camber allowed for settlement, curbs, parapets, guard rails or other structures that are not a part of the main water-retaining structure. It can include a roadway, walkway or the non-overflow section of a dam.

DAM: An artificial barrier that would create a water storage reservoir or divert water, and includes appurtenances necessary for the barrier.

DAM EMERGENCY: Any condition that develops naturally or unexpectedly, endangers the integrity of the dam and upstream or downstream property or life, and requires immediate attention.

DAM EMERGENCY PLAN: A plan prepared by a dam owner under sections 9 and 33 of the Dam Safety Regulation that describes the actions the dam owner will take in the event of an emergency at a dam.

DAM FAILURE: Sudden, rapid, and uncontrolled release of impounded water or the likelihood of such an uncontrolled release.

DAM OWNER: A person, company, organization, government unit, public utility, corporation or other entity that holds or should hold a water licence to operate a dam or retains the legal property title on the dam site, dam and/or reservoir, or the person who constructed the dam.

DAM SAFETY OFFICER: An engineer or officer who is designated in writing by the comptroller as a dam safety officer.

DAM SAFETY REGULATION: A B.C. regulation under the *Water Sustainability Act* aimed at mitigating the loss of life and damage to property and the environment from a dam breach. It requires that dam owners inspect their dams, undertake proper maintenance on them, and ensure they meet current engineering standards.

FULL SUPPLY LEVEL: Maximum normal operating water surface level of a reservoir (also called maximum normal level). It is generally the spillway sill elevation.

GATE (OUTLET GATE): A general term for any mechanical device to control the flow of water in intakes, outlet works and over spillways.

GROUT: A viscous material injected into soil, rock, concrete, or other construction material to seal openings, lower the permeability and/or provide additional structural strength.

HEIGHT OF DAM: The difference in elevation from the lowest foundation level (base of dam) usually at the downstream toe to the crest of the dam.

HOMOGENEOUS DAM: An embankment earthfill or rockfill dam, made with more or less uniform materials throughout, except for possible drain layer. Used to differentiate from a zoned dam that has distinct parts or zones of different material.

INSTRUMENTATION: Devices installed in or near a dam to monitor it and its reservoir, e.g. survey monuments and stations, inclinometers, extensometers, piezometers, measuring weirs.

INTERNAL EROSION (PIPING): The progressive erosion of material from within a dam caused by seepage, appearing downstream as a hole or seam discharging water that contains solid particles.

LOG-BOOM: A series of floating logs lashed (preferably with boom chain) end to end, and placed on the reservoir surface at a line just upstream of the dam in order to prevent trash, ice and floating debris from entering the spillway or outlet works.

LOW-LEVEL OUTLET (ALSO SEE OUTLET WORKS): A conduit through the dam to allow for controlled release of water from the reservoir.

MAINTENANCE: Tasks accepted as routine in keeping the dam and appurtenant works in a serviceable condition. Not to be confused with alterations. Tasks considered as maintenance may be carried out under Section 7 of the *Water Sustainability Act*.

DAM SAFETY REVIEW: Comprehensive formal review carried out at regular time intervals to determine whether an existing dam is safe, and if it is not safe, to determine what improvements are required.

DRAWDOWN: Lowering the water surface level through a controlled release of water from the reservoir.

EARTHFILL DAM: A dam constructed primarily of compacted mineral soils and aggregate.

EMBANKMENT DAM: A dam constructed of excavated natural material, such as earth or rock, or of industrial waste materials. It includes zoned-fill dams with selected areas of rock, gravel and impervious zones, or homogeneous earthfill dams, which are not necessarily zoned.

ENGINEERING PROFESSIONAL:

a. a professional engineer as defined in the *Engineers and Geoscientists Act*, or

b. a holder of a limited licence under the *Engineers and Geoscientists Act* that permits the person to practice professional engineering and who is acting within the scope of the limited licence.

EROSION: The wearing away of a surface (bank, streambed, embankment, or other surface) by floods, waves, wind, or any other natural process.

FAILURE OF DAM: In terms of structural integrity, the uncontrolled release of the contents of a reservoir through collapse of the dam or some part of it; in terms of performance to fulfill its intended function, the inability of a dam to perform functions such as water supply or prevention of excessive seepage.

FORMAL INSPECTION: An inspection that is more thorough than a surveillance inspection, carried out by the dam owner, an engineering consultant or a person responsible for the dam's safety.

FOUNDATION: Rock and/or soil mass that forms a base for the dam structure, including its abutments.

FREEBOARD: Vertical distance between the water surface elevation and the lowest elevation to the top of the dam or other containment structure.

OPERATION, MAINTENANCE & SURVEILLANCE MANUAL (OMS): A manual that documents procedures for the safe operation, maintenance and surveillance of a dam.

OUTLET WORKS: Combination of intake structure, gates, conduits, tunnels, flow controls and energy dissipation devices to allow the release of water from the reservoir.

PROFESSIONAL ENGINEER: Individual registered or licenced under the *Engineers and Geoscientists Act*, and has knowledge, skills and experience in dam design, construction and maintenance.

REPAIR: To restore a dam to its approved design conditions. With older dams, a dam safety officer can advise if it needs to be upgraded to meet current design conditions.

PENSTOCK: A pressurized pipeline or shaft between the reservoir and hydraulic machinery, usually a turbine.

PIPING: The progressive development of internal erosion by seepage.

RESERVOIR: A body of water impounded by a dam and in which water can be stored.

RIPRAP: A layer of well-graded broken (angular) rock, generally placed on the upstream slopes of an embankment or along a watercourse as protection against wave action, erosion or scour.

SAFE DAM: Dam which meets safety criteria acceptable to government, the engineering profession and the public.

SCADA: Acronym for Supervisory Control and Data Acquisition, a computer system for gathering and analyzing real time data relating to the operation and monitoring of a dam.

SEEPAGE: Flow or movement of water through a dam, its foundation or abutments.

SETTLEMENT: The vertical downward movement of a structure or its foundation.

SLOPE PROTECTION: The protection of a slope against wave action or erosion. See Riprap.

SPILLWAY: A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means, such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway.

SPILLWAY CAPACITY: The maximum spillway outflow that a dam can safely pass with the reservoir at its maximum level.

SPILLWAY CHANNEL: An open channel or closed conduit conveying water from the spillway inlet downstream.

SPILLWAY SILL: Control level of the spillway overflow section.

STORAGE: Collection, impounding and conservation of water. Types include:

- **NATURAL STORAGE:** *What is/was natural body of water, e.g. existing pond.*
- **DEAD STORAGE:** *Normally what is between upstream toe and outlet sill, not accessible with permanent outlet works.*
- **LIVE STORAGE:** *Accessible storage, from low level outlet to spillway sill.*
- **LICENCED STORAGE:** *Typically equal to the live storage.*
- **SURCHARGE STORAGE:** *Typically from spillway sill to design flood level.*

SURVEILLANCE INSPECTION: An inspection performed by the dam owner as a regular part of routine maintenance.

TOE OF DAM: Junction of the downstream (or upstream) face of dam with the ground surface (foundation). Sometimes heel is used to define the upstream toe of a concrete gravity dam.

TRASH RACK: A device located at an intake to prevent floating or submerged debris from entering the intake.

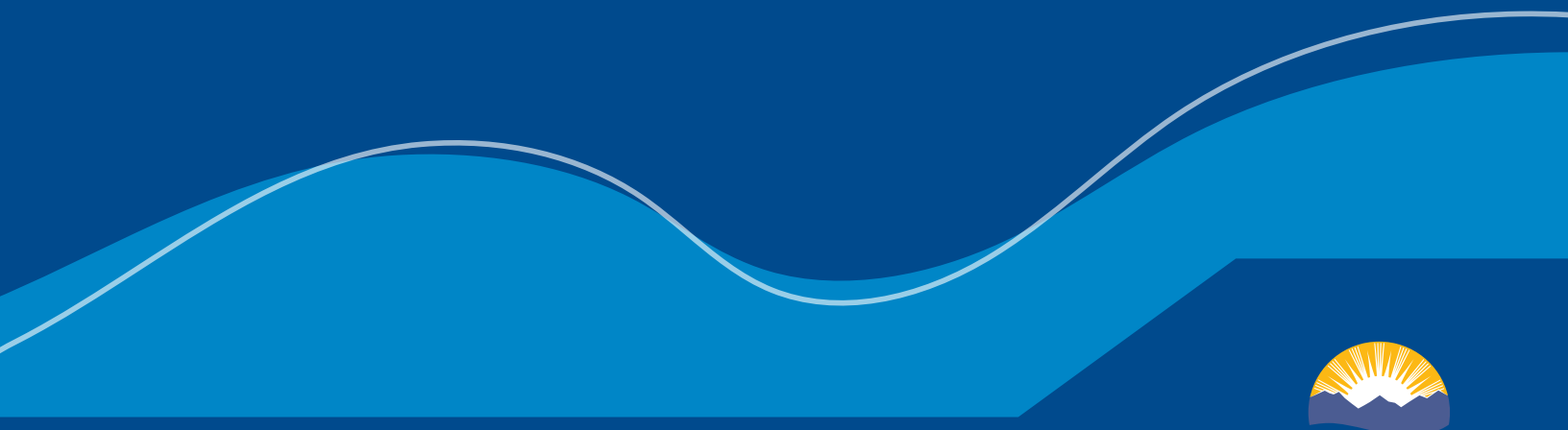
UPSTREAM SLOPE: The inclined surface of the dam that is in contact with the reservoir.

WATER MANAGER: A Crown employee designated in writing by the minister, including an acting or assistant water manager.

WORKS: Anything capable of or used for diverting, storing, measuring, conserving, conveying, retarding, confining or using water, or producing, transmitting or using electricity.

ZONED DAM: An embankment dam that has distinct parts or zones of different material.

Notes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