Dam Safety Guidelines

Inspection & Maintenance of Dams
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This guide book is intended to give owners of small dams (those under 15 metres in height) a basic understanding of the dam owners responsibilities with regard to the inspection, operation, maintenance, and reporting procedures for their dams. Large dams (those over 15 metres in height) may require additional operation, maintenance, surveillance (inspection), and reporting procedures that are specific to that particular dam.

The Inspection and Maintenance of Dams guide book has been prepared by the Dam Safety Section of the Provincial Government to promote Dam Safety in British Columbia. The guide book should educate dam owners on; their liabilities and responsibilities, the potential risk dams pose, why regular inspections and routine maintenance on dams are necessary, appropriate inspection and maintenance techniques, how to prepare for a dam related emergency, and provide a basis for discussion between a dam owner and ministry staff. Some of the templates originally found in this guideline are now available for download on the Dam Safety in BC website. Other technical resources such as brochures, checklists and guidelines are also available on the Dam Safety in BC website. Please check regularly for updates.

The Dam Safety Regulation, proclaimed in February, 2000 and revised in 2016, applies to all dam owners. Dam owners should familiarize themselves with the regulations and comply with the requirements which are based on the downstream consequence classification of their dam(s).

While this guide will aid the dam owner in determining how serious a dam deficiency may be, it is not intended to be a guide to solve severe structural deficiencies. Severe structural deficiencies and solutions for repair may require the services of a qualified professional Engineering consultant with knowledge and experience with dam construction and remedial work.

Note: This booklet should not be relied upon in any manner as a document for design and/or construction of dams.
### SECTION 1 - DEFINITIONS

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abutment</td>
<td>That part of the valley side against which the dam is constructed.</td>
</tr>
<tr>
<td>Appurtenances</td>
<td>Structures and equipment on a project site, other than the embankment itself. They include, but are not limited to facilities, such as spillways, log booms, intake towers, powerhouse structures, tunnels, canals, penstocks, low-level outlets, surge tanks and towers, gate hoist mechanisms and their supporting structures, and all critical water control and release facilities. Also included are mechanical and electrical control and stand-by power supply equipment located in the powerhouse or in remote control centers.</td>
</tr>
<tr>
<td>Breach of Dam</td>
<td>The uncontrolled release of the contents of a reservoir through collapse of the dam or appurtenant structures.</td>
</tr>
<tr>
<td>Comptroller</td>
<td>A person employed by the government and designated in writing by the minister as the Comptroller of Water Rights and includes any persons designated in writing by the minister as acting, deputy or assistant comptrollers.</td>
</tr>
<tr>
<td>Consequences of Dam Failure</td>
<td>Impacts in the downstream as well as upstream areas of the dam resulting from failure of the dam or its appurtenances. Refer to Schedule 1 of the Dam Safety Regulation.</td>
</tr>
<tr>
<td>Crest of Dam</td>
<td>Elevation of the uppermost surface of a dam proper, 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. This elevation may be roadway, walkway or the non-overflow section of a dam.</td>
</tr>
<tr>
<td>Dam</td>
<td>A man made barrier that would create a water storage reservoir or divert water. “Dam” is herein defined to include works (appurtenances) incidental to, necessary for, or in connection with, the barrier.</td>
</tr>
<tr>
<td>Dam Owner</td>
<td>A person, including a company, organization, government unit, public utility, corporation or other entity, which either holds a water licence to operate a dam or retains the legal property title on the dam site, dam and/or reservoir, or a person who acts as the principal agent of the dam owner and which is responsible for the safety of the dam.</td>
</tr>
<tr>
<td>Dam Safety Officer</td>
<td>An engineer or officer who is designated in writing by the comptroller as a dam safety officer.</td>
</tr>
<tr>
<td>Dam Safety Regulation</td>
<td>Means the British Columbia Dam Safety Regulation passed into law under the Water Act whose objective is to mitigate loss of life and damage to property and the environment from a dam breach by requiring dam owners to inspect their own dams, undertake proper maintenance on them, and ensure that these dams meet ongoing engineering standards.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>Dam Safety Review</td>
<td>Comprehensive formal review carried out at scheduled intervals to determine whether an existing dam is safe, and if it is not safe, to determine what improvements are required.</td>
</tr>
<tr>
<td>Drawdown</td>
<td>The resultant lowering of water surface level due to controlled release of water from the reservoir.</td>
</tr>
<tr>
<td>Earthfill Dam</td>
<td>See “Embankment Dam”.</td>
</tr>
<tr>
<td>Embankment Dam</td>
<td>Any dam constructed of natural excavated materials placed without addition of binding materials other than those inherent in the natural material. The materials are usually obtained at or near the dam site. Embankment dams are usually referred to by type such as Earthfill or Rockfill. The term Embankment Dam is used to indicate a zoned fill dam involving selected areas of rock, gravel and impervious zones or a homogeneous earthfill dam which is not necessarily zoned.</td>
</tr>
<tr>
<td>EMBC</td>
<td>See PEP</td>
</tr>
<tr>
<td>Emergency</td>
<td>In terms of dam operation, any condition which develops naturally or unexpectedly, endangers the integrity of the dam and upstream or downstream property or life, and requires immediate action.</td>
</tr>
<tr>
<td>Dam Emergency Plan (DEP)</td>
<td>Document which contains procedures for dealing with various emergencies, as well as communication directories and may contain inundation maps showing upstream and downstream water levels and times of arrival of floods which would result from the failure of the dam or its appurtenances.</td>
</tr>
<tr>
<td>Engineer</td>
<td>A professional engineer employed by the government and designated in writing by the Comptroller of Water Rights as an engineer and includes a regional water manager.</td>
</tr>
<tr>
<td>Failure of Dam</td>
<td>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 fulfil its intended function, the inability of a dam to perform functions such as water supply or prevention of excessive seepage.</td>
</tr>
<tr>
<td>Formal Inspection</td>
<td>An inspection of the dam to observe its condition. A formal inspection is intended to be more thorough than a routine surveillance inspection. These inspections are carried out by the appropriate representative of the dam owner responsible for safety surveillance (i.e. the dam owner or owners engineering consultant).</td>
</tr>
<tr>
<td>Foundation</td>
<td>Rock and/or soil mass that forms a base for the structure, including it abutments.</td>
</tr>
<tr>
<td>Freeboard</td>
<td>Vertical distance between the dam crest and the reservoir water surface. The more specific term “normal (Gross) freeboard” is the difference of elevation between the lowest elevation of the top of the dam (or top of impervious core) and the maximum reservoir operating level (full supply level, often the spillway sill elevation). The term</td>
</tr>
</tbody>
</table>
“Minimum (Net) Freeboard” is the difference of elevation between the lowest elevation of the top of the dam (or top of impervious core) and the maximum water level of the reservoir should the Inflow Design Flood (IDF) occur.

Full Supply Level
Maximum normal operating water surface level of a reservoir (also called maximum normal reservoir water level). Generally the spillway sill elevation.

Gate
A general term for any mechanical device to control the flow of water in intakes, outlet works and over controlled spillways.

Height of Dam
The vertical distance to the top (crest) of a dam measured:
   a) in the case of a stream across a stream, from the natural bed of the stream at the downstream outside limit of the dam, or
   b) in the case of a dam that is not across a stream, from the lowest elevation at the outside limit of the dam.

Homogeneous Earthfill Dam
An embankment type dam constructed of more or less uniform earth materials throughout, except for possible inclusion of internal drains or blanket drains. Used to differentiate this type of dam from a zoned earthfill dam.

Inspection
See “Formal Inspection” & “Surveillance Inspection”

Instrumentation
Devices which are installed in or near a dam to monitor the dam and impoundment. These devices may include but are not limited to survey monuments and stations, inclinometers, extensometers, piezometers, measuring weirs.

Internal Drain or Drainage Blanket
A layer of pervious material in a dam to facilitate drainage.

Internal (piping) Erosion
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 connected (preferably with boom chain) end to end, and placed on the reservoir surface at a line just upstream of the dam in order to collect trash, ice and floating debris and prevent their entrance to spillway or outlet works.

Low-Level Outlet
A conduit through the dam to allow for controlled release of the reservoir contents. Also see “Outlet Works”.

Maintenance
Those tasks accepted as routine in keeping the dam and appurtenant works in a serviceable condition. It is not to be confused with alterations.

A Manual which documents procedures for safe operation, maintenance and surveillance of a dam.

Outlet Gate
See “Gate”.

Section 1 - Definitions
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlet Works</td>
<td>Combination of intake structure, gates, conduits, tunnels, flow controls and energy dissipation devices to allow the release of water from a dam.</td>
</tr>
<tr>
<td>Owner</td>
<td>See “Dam Owner”</td>
</tr>
<tr>
<td>Piping</td>
<td>See “Internal Erosion”.</td>
</tr>
<tr>
<td>Professional Engineer</td>
<td>A person who is registered or licenced under provisions of the Engineers Act, 1979, RS Chapter 109 of the Province of British Columbia and has knowledge, skills and experience in dam design, construction and maintenance. Regional Water Manager; A person employed by the Crown and designated in writing by the minister as a regional water manager and includes an acting or assistant regional water manager. Reference to the Regional Water Manager means the designated person for the geographic location or Water District where the works are located.</td>
</tr>
<tr>
<td>PEP</td>
<td>Provincial Emergency Program continued under the Emergency Program Act. Also referred to as Emergency Management BC (EMBC).</td>
</tr>
<tr>
<td>Regional Water Manager</td>
<td>A person employed by the Crown and designated in writing by the minister as a regional water manager and includes an acting or assistant regional water manager. Reference to the Regional Water Manager means the designated person for the geographic location or Water District where the works are located.</td>
</tr>
<tr>
<td>Repair</td>
<td>To essentially restore a dam to its approved design condition. Many older dams may be required to be upgraded to current design standards if there is a difference between the initial approved design and current design standards.</td>
</tr>
<tr>
<td>Reservoir</td>
<td>Water body impounded by one or more dams, inclusive of its shores and banks and of any facility or installation necessary for its operation.</td>
</tr>
<tr>
<td>Right Abutment</td>
<td>The abutment on the right-hand side of an observer when looking downstream.</td>
</tr>
<tr>
<td>Riprap</td>
<td>Layered broken (angular) rock or precast blocks, generally placed on the upstream slopes of an embankment or along a water course as protection against wave action, erosion or scour. Riprap should be properly placed by mechanical methods and in some cases is hand placed. It consists of pieces of relatively large size as distinguished from a gravel blanket.</td>
</tr>
<tr>
<td>Rockfill Dam</td>
<td>See “Embankment Dam”.</td>
</tr>
<tr>
<td>Safe Dam</td>
<td>Dam which does not impose an unacceptable risk to people or property, and which meets safety criteria that are acceptable to the government, the engineering profession and the public.</td>
</tr>
<tr>
<td>SCADA</td>
<td>Acronym for Supervisory Control and Data Acquisition, a computer system for gathering and analyzing real time data. SCADA systems can be used to monitor and control various components of a dam.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>Spillway</td>
<td>Weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the reservoir.</td>
</tr>
<tr>
<td>Spillway Sill</td>
<td>The control level of the spillway overflow section.</td>
</tr>
<tr>
<td>Stoplogs</td>
<td>Large logs, timbers, concrete or steel beams stacked vertically on each other so as to close off entrance to dam outlets or penstocks. Normally stoplogs are used intermittently as temporary outlet gates in order to effect repairs or replacements to the permanent facilities</td>
</tr>
<tr>
<td>Storage</td>
<td>The collection, impounding and conservation of water. Type of storage are:</td>
</tr>
<tr>
<td>Natural Storage</td>
<td>what is/was the natural body of water (i.e. the existing lake or pond).</td>
</tr>
<tr>
<td>Dead Storage</td>
<td>created storage not accessible with the permanent outlet works. This is normally between the upstream toe and the outlet sill. It may include what was natural storage if the toe of the dam is contructed below the natural lake outlet.</td>
</tr>
<tr>
<td>Live Storage</td>
<td>the accessible storage, typically from low level outlet sill to spillway sill.</td>
</tr>
<tr>
<td>Licenced Storage</td>
<td>typically includes dead storage plus live storage.</td>
</tr>
<tr>
<td>Surcharge Storage</td>
<td>typically from the spillway sill to design flood level.</td>
</tr>
<tr>
<td>Tailwater Level</td>
<td>Level of water in the discharge channel immediately downstream of a dam.</td>
</tr>
<tr>
<td>Toe of Dam</td>
<td>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.</td>
</tr>
<tr>
<td>Top of Dam -</td>
<td>See “Crest of Dam”.</td>
</tr>
<tr>
<td>Trashrack</td>
<td>A screen or grill structure placed at the inlet end of penstocks and low level outlets to prevent the entrance of logs, timbers, trash or other debris from the reservoir.</td>
</tr>
<tr>
<td>Surveillance Inspection</td>
<td>An inspection performed by the dam owner as a regular part of their routine maintenance activities.</td>
</tr>
<tr>
<td>Works</td>
<td>Anything capable of or used for diverting, storing, measuring, conserving, conveying, retarding, confining or using water, or producing, measuring, transmitting or using electricity.</td>
</tr>
<tr>
<td>Zoned Earthfill Dam</td>
<td>See “Embankment Dam”.</td>
</tr>
</tbody>
</table>
SECTION 2
BACKGROUND

1. What is a Dam?
Simply stated, a dam is a man made barrier constructed for the purpose of storing water. Commonly used dam related terminology can be found in Section 1, Definitions, located at the beginning of this guide book.

The two most common types of dams constructed around the world are embankment dams and concrete dams. The majority of the approximately 2600 dams constructed in British Columbia are earthfill embankment dams.

A dam consists of a variety of different components, each having its own unique potential problem area and inspection requirement. The main components that make up a dam include: earth or concrete barrier, abutments, foundation, outlet, spillway and gates. See Figure No. 1 for the principle parts of a dam, Figure No. 2 for a typical cross section and Figure No. 3 for a typical catchment area.

2. Why should a Dam Owner have a Dam Safety Program?
Dams, by their very nature, create risks. Although these risks may be minimal, they can increase substantially without proper maintenance. Many subtle signs which can be symptomatic of larger problems may go unnoticed for a variety of reasons. Sooner or later these problems will become apparent even to the untrained eye. However, by the time a problem has progressed to this point, potential risk has greatly increased and repairs can become complex and extremely expensive. In most situations a Dam Safety Program that includes regular preventative maintenance, routine surveillance inspections, and the identification of problems in their early stages will ensure that the dam remains in good operating condition.

What is a Safe Dam?
According to the U.S. Bureau of Reclamation, “A safe dam is one which performs its intended functions without imposing unacceptable risks to the public by its presence.”
3. Who is Responsible for Dam Safety?

In all cases, dam owners are clearly responsible for the safe operation and maintenance of their dams. English common law, on which our legal system is based, considers dams to be inherently dangerous structures and those who own dams are liable for any damages that are caused by them.

The Water Act of British Columbia requires that a water licence be issued if water is to be stored and works constructed. The registered licensee, be it a private individual or a corporation thus becomes the ‘dam owner’. Section 21(1) of the Water Act states:

“A licensee, holder of an approval or person who makes a change in and about a stream in accordance with the regulations must

(a) exercise reasonable care to avoid damaging land, works, trees or other property, and
(b) make full compensation to the owners for damage or loss resulting from construction, maintenance, use, operation or failure of the works.”

Or in other words, the dam owner is responsible for ensuring that their dam and appurtenant works are structurally sound, operated safely and maintained adequately to prevent loss of life, damage to the environment, or adverse social impact such as loss of communal water supply or infrastructure from a dam failure.

4. What is Expected of the Dam Owner?

The dam owner’s expected actions include:

- thorough surveillance inspections, accurate monitoring when required;
- recording and interpreting information gained from inspection and monitoring;
- regularly scheduled routine maintenance;
- making required repairs in a timely manner;
- preparing Operation, Maintenance & Surveillance plans and manual when required;
- preparing Dam Emergency Plans when required; and
- operating the dam in a way that will give the greatest assurance of safety.

The required intensity of effort will vary in relation to the loss that would be experienced in terms of loss of life, the downstream development, and the value of the structure itself.
5. What is the Provincial dam Safety Program?

The Provincial Dam Safety Program was instituted by the Comptroller of Water Rights in 1967 as an aid to dam owners for the purpose of ensuring that their structures are designed, constructed and maintained according to acceptable standards for public safety. The Provincial Dam Safety Program encompasses two components, regional (Provincial Government, Regional Offices) and headquarters (Water Management Branch, Victoria). See Page 56 for contact information.

Dam Safety Officers located in each region and in Victoria are responsible for ensuring that the dams in their jurisdiction do not pose an unacceptable risk to life, property and/or the environment. In general, headquarters jurisdiction covers dams over 9 metres in height, the majority of which are owned by local authorities, large corporations and power utilities. The regional jurisdiction, on the other hand, covers dams under 9 metres in height which are generally owned and operated by

It is important to note that the probability of small dams failing can be much higher than larger dams due to the lack of owner resources resulting in poorer maintenance. Even a relatively small dam can have severe consequences in the event of a failure. Therefore, the Provincial Dam Safety Program places a high priority on ensuring the safety of all dams in BC.

6. What will I find in this Booklet?

Section 1 contains common Definitions. Section 2 is an Introduction to Dam Safety, Section 3 describes Modes of Dam Failures, Sections 4 and 5 provide details on Inspecting and Maintaining Dams and Section 6 outlines how to set up an Operation, Maintenance and Surveillance Plan. A Self Help Guide to assist dam owners in dealing with specific problems is found in Section 7.

The following can be found in Section 8:
• a guide for preparing an Operation, Maintenance and Surveillance plan,
• a deficiency checklist and,
• a dam inspection checklist/formal report form.

Note: Additional copies of the checklists can be obtained from your regional Water Management Offices and our website: www.env.gov.bc.ca/wsd/

Figure No. 3 - Typical Catchment Area
1. Historic Dam Failures in British Columbia

There have been dam failures in British Columbia from as far back as the turn of the century to as recently as June 13, 2010. The following are examples:

- In 1912, a small water supply dam servicing the coal shipping port of Union Bay on Vancouver Island failed, killing one man and causing extensive damage to property and the coal loading port facilities.
- In 1941, a 10 metre high dam located above the town of Penticton failed resulting in severe damage to the downstream area. If the dam had failed with today’s population living below, damage to business and property would be extensive and loss of life would have been likely.
- On May 27, 1995, a 5 metre high earthfill irrigation dam failed causing approximately half a million dollars damage. The sudden release of 150 acre-feet of storage killed 48 head of cattle, destroyed 1.5 kilometers of public road, damaged 100 acres of hay field and introduced 700,000 cubic metres of debris into the Quesnel River. Three ranchers barely escaped with their lives.

2. What Can Cause a Dam to Fail?

Dams can develop problems or fail for a number of reasons. Deficiencies in the design, poor construction practices/materials, inadequate spillway capacity and poor foundation conditions are the most common structural failure. During operation a dam can develop problems or fail for reasons related to poor operations and maintenance, or conditions beyond the control of the owner/operator. Although rare, failures can and do occur.

3. Modes of Embankment Dam Failures

There are three predominant causes of embankment dam failures: External Erosion Failures, Internal Erosion Failures and Structural Failures. These failures are outlined by types, characteristics, causes and preventative measures in Tables 1, 2, and 3 on pages 15 & 16.

a) External Erosion Failure

External erosion failure may result from; the uncontrolled flow of water over the dam, around the dam, and adjacent to the dam, plus the erosive action of water on the dam. Earth embankment dams are particularly susceptible to external erosion failure since the fill material erodes easily with relatively low velocity flows.

If adverse conditions occur the reservoir may rise to a level above the crest of the dam causing the stored water to flow over the crest. This flow may then start eroding the embankment material. If severe erosion damage is
not dealt with immediately, embankment failures can result.

b) Internal Erosion (Piping) Failure
While dams are designed to be as impervious as possible, some water does manage to flow through, under or around them. This is referred to as seepage. Seepage can appear as a soft wet area, as standing water or, in some cases, as a flowing spring. Clear seepage is generally not a serious problem if adequate drains and filters are provided to prevent the transport of fill material (see typical cross-section of a dam, Figure 2) and if the seepage water is not allowed to pond at the downstream toe. Seepage can emerge on the downstream slopes, below the toe of the dam or on the downstream abutments.

The presence of seepage may be identified by a change in vegetation. Once identified, the seepage area should be defined and marked with stakes or pegs, so that any variation in size can be noted. Seepage areas on the downstream slope should be considered serious and closely watched as it can lead to a slope failure. Seepage water which is dirty is indicative that erosion of the fill material is occurring which may lead to the failure of the dam by progressive erosion (piping) if remedial action is not taken.

c) Structural Failure
Structural failure can occur in the abutments, foundation and the embankment slopes. Factors which affect structural stability can include poor foundation conditions, poor construction practices and poor fill materials or inadequate slopes and seepage.

Structural failure of a dam can be observed in its early stages by the presence of cracks, excessive settlement and misalignment of the crest. Cracks can appear on the crest or the slopes and can be longitudinal or transverse. The types of cracks, their causes and consequences are illustrated in the Self-Help Guide of Section 7. The development of a slope failure from longitudinal cracking and the development of a failure from transverse cracking are shown in Figures 8 and 9 respectively.

Structural failure can also occur in appurtenant works including spillway structures, outlets and gates. Failure of these structures may lead to the failure of the dam.

4. Modes of Concrete Dam Failures
Although people tend to think of concrete dams as more permanent structures than embankment dams, failure of a concrete dam is often more catastrophic. Because they have less obvious symptoms prior to failure, collapse may be very rapid, with little or no advance warning. Concrete dams are nearly immune to the kinds of failures that affect embankment dams, such as erosion during overtopping, embankment instability, and piping failures. Concrete dam failures, by contrast, usually fall into one of the following categories:

- Overturning or Sliding, resulting from erosion of the supporting foundation and/or abutments,
• Abutment or foundation failure due to over-stressing, or
• Structural failure of concrete unable to sustain imposed loads.

![Figure No. 6 - Ellis Creek Dam Failure (near Penticton) 1941.](image)

**Table 1 - External**

<table>
<thead>
<tr>
<th>Form of External Erosion Failure</th>
<th>Characteristics</th>
<th>Causes</th>
<th>Preventative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overtopping erosion</td>
<td>Flood water flows over embankment washing out the dam</td>
<td>Inadequate spillway capacity</td>
<td>Design the spillway with adequate capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improper operation of diversion-fed reservoirs</td>
<td>Stop diversion into storage when reservoir is full</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clogging of spillway with debris</td>
<td>Install logboom where possible and periodically remove debris</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Insufficient freeboard due to settlement or erosion of embankment</td>
<td>Regrade crest to design elevation. Draw down reservoir through low level outlet</td>
</tr>
<tr>
<td>Wave erosion</td>
<td>Upstream slope eroded</td>
<td>Inadequate riprap or lack of filters</td>
<td>Place layered riprap and filters</td>
</tr>
<tr>
<td>Toe erosion</td>
<td>Erosion of embankment toe near spillway or outlet</td>
<td>Spillway or outlet located too close to dam</td>
<td>Discharge water away from the embankment and provide erosion protection</td>
</tr>
<tr>
<td>Surface erosion</td>
<td>Surface runoff from rain or snowmelt eroding the downstream slope of dam</td>
<td>Poor surface drainage and lack of adequate grass cover on the downstream slope</td>
<td>Provide drains or ensure adequate grass cover on the downstream face</td>
</tr>
</tbody>
</table>
Table 2 - Internal Erosion Failure

<table>
<thead>
<tr>
<th>Form of Internal Erosion Failure</th>
<th>Characteristics</th>
<th>Causes</th>
<th>Preventative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piping</td>
<td>Progressive internal erosion of material usually starting from downstream side of</td>
<td>Concentrated seepage</td>
<td>Install toe drains or filters</td>
</tr>
<tr>
<td></td>
<td>dam or foundation and progressing upstream, eventually leading to a breach</td>
<td>Seepage along conduit</td>
<td>Grout along conduit to fill voids or replace conduit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leaking conduit</td>
<td>Seal joints, reline conduit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tree roots</td>
<td>Remove before they become a problem</td>
</tr>
</tbody>
</table>

Table 3 - Structural Failures

<table>
<thead>
<tr>
<th>Type of Structural Failure</th>
<th>Characteristics</th>
<th>Causes</th>
<th>Preventative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation failure</td>
<td>Sliding of one or both slopes with heaving of the toe in direction of movement</td>
<td>Soft or weak foundation</td>
<td>Flatten slope. Construct toe berms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Excess water pressure in</td>
<td>Provide drains and filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>foundation</td>
<td></td>
</tr>
<tr>
<td>Upstream slope failure</td>
<td>Slide in upstream slope</td>
<td>Slope too steep</td>
<td>Flatten slope, Construct berm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rapid reservoir drawdown</td>
<td>Avoid rapid lowering of reservoir</td>
</tr>
<tr>
<td>Downstream slope failure</td>
<td>Slide in downstream slope</td>
<td>Slope too steep</td>
<td>Flatten Slope, Construct toe berm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Saturation of slope by seepage</td>
<td>Provide proper drainage by installing filter blanket or</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>toe filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corroded outlet works</td>
<td>Inspect and repair any corrosion</td>
</tr>
<tr>
<td>Spillway failure</td>
<td>Overtopping of the dam</td>
<td>Spillway blocked or undersized</td>
<td>Install a log boom to prevent debris from entering,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for the design flood.</td>
<td>replace spillway with one of adequate size</td>
</tr>
<tr>
<td></td>
<td>Erosion along spillway walls leading to a breach</td>
<td>Seepage along the spillway</td>
<td>Monitor for seepage and repair if excessive. See “Piping”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>walls</td>
<td>Table 2</td>
</tr>
<tr>
<td>Reservoir bank slide</td>
<td>Slough or slide into the reservoir may cause overtopping of the dam if</td>
<td>Toe of unstable slope</td>
<td>Stabilize slope by adding berm material or draining</td>
</tr>
<tr>
<td></td>
<td>sufficiently large and occurring quickly</td>
<td>saturated by impounded water</td>
<td>Maintain reservoir elevation below slide area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure No. 7 - Development of a Slope Failure from Longitudinal Cracking

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
**A - Initial Transverse Cracking**
Often caused by settlement, foundation problems or placement of fill over steep abutments.

**B - Progression of Transverse Cracking to a point below the waterline**
Water from the reservoir begins to flow through the crack.

**C - Transverse Cracking progressed to an overtopping situation**
Condition has progressed to a point of imminent failure.

*Figure No. 8 - Development of a Failure From Transverse Cracking.*
1. Inspection Guidelines
The purpose of a dam inspection program is to identify problems and/or unsafe conditions. Inspection is an integral part of a proper maintenance program for a dam. Failure to correct identified maintenance and repair items could result in the failure of a dam. See Figure No. 10 for indicators of potential problems. Watch for the noted indicators during all surveillance inspections.

2. When should an Inspection be done?

a) Performing Surveillance inspections
on a regular basis, as part of the routine maintenance is the most economical means of assuring the safety and long life of the structure. Routine surveillance inspections are a straightforward procedure that allows any properly trained person to make an accurate assessment of a dam’s condition. The inspection involves careful examination of the surface of all parts of the structure.

Routine surveillance inspections should be carried out as appropriate for the item being inspected and the frequency based upon the dam’s consequence classification (refer to Schedule 2 of the Dam Safety Regulation). Table 4 on page 22 lists some common problems associated with small dams and suggested times for enhanced surveillance and inspection.

Reduced frequencies of the routine surveillance inspections may need to be selected to suit seasonal conditions (i.e. snowcover). Seepage readings (or any other condition that is subject to change) should be measured and recorded. Reservoir level, operational conditions, outlet and spillway releases should also be recorded as this may give insight into any deficiencies found on the dam. Site surveillance forms are provided in Section 8 and on the Dam Safety in BC website.

Some of the best times to look at a dam are:

- In the late spring or early summer when the reservoir is at Full Supply Level (FSL) (seepage which might occur under, through or around the dam will be most noticeable at FSL), In the late summer or early fall when the reservoir is drawn down (exposing the upstream face to allow for closer inspection),
- after severe weather events such as heavy rainfall, flooding, windstorms, severe icing, rapid snowmelt, etc.,
- After a severe seismic event.

b) Formal Inspections - are intended to be a more thorough inspection performed by the appropriate representative of the owner (i.e. the individual responsible for safety surveillance). The frequency required for formal inspection and maintenance based on consequence classification can be found in Schedule 2 of the
Figure No. 10 - Potential Problem Indicators
Dam Safety Regulation, a copy of which can be obtained from any Regional office as well as the website. The formal inspection shall be recorded in a formal inspection report and kept by the dam owner as an historical record. Depending on the complexity of the dam, the consequence classification of the dam and the requirements of the Dam Safety Officer, use of the site surveillance form, located in Section 8, may be all that is required. A more comprehensive inspection checklist “Formal Annual Inspection” is available on the website. Copies of these formal inspection reports may be requested by the Dam Safety Officer for audit.

Note: Evaluation of the conditions downstream of the dam must be undertaken at the same time as the formal inspection to ensure the consequence classification of the dam has not changed. Any changes must be reported to the Dam Safety Officer. A list of Regional and Headquarters (Victoria) Offices and their telephone numbers can be found on page 56 and on our website.

c) A Dam Safety Review - involves the collection of all available dam records, field inspections and detailed assessment of the structural and hydrologic features of the dam. A DSR is not required for significant and low consequence dams. It then proceeds with a check of structural stability and operational safety of the dam, beginning with a reappraisal of basic features and design assumptions.

The level of detail required in a Dam Safety Review should be proportional with the importance and complexity of the dam, as well as the consequences of failure. Refer to the guide for preparation of a Dam Safety Review on our Dam Safety of BC website.

3. What equipment is required to do an Inspection?

The purpose of a dam safety inspection is to gather and record facts that may have an impact on the safety of the dam. Use the SMPL (Simple) rule for all recordings:

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 some standard reference point.

The following are a few of the basic items that aide the owner in doing a surveillance inspection:

• clip board
• tape measure/ruler
• field notebook/inspection checklist
• camera/video
• pencils and a flashlight.

4. What is involved in an Inspection?

It is helpful to have a system or method of inspection which can be repeated consistently. By organizing and listing the various components of a dam in the form of an inspection report, a methodical approach for inspection can be easily developed. A dam inspection checklist can be found in Section 8 of this booklet. It is recommended that the dam owner download a copy of the Inspection Checklist from the website and modify it to suit the requirements of each individual dam.

A review of notes from previous inspections, photographs and ‘As Constructed’ drawings, if available, should precede the actual field inspection. This will allow comparison of the present condition to the ‘As Constructed’ condition or its condition at the time of the previous inspections.

The inspection itself should include all of the components of the dam; the crest, upstream and downstream embankments, the abutments, the spillway, the reservoir banks, and the area below the dam. Any gates or control valves associated with the spillway and/or low level outlet should be inspected and tested if possible to ensure that they are operational. This includes a close examination of all accessible moving parts.

The inlet and outlet structures should be inspected with close attention given to the internal condition of any conduit, pipes or access wells. Anything unusual or anything that has changed since the last inspection should be noted (i.e. new or increased erosion, settlement, cracks, seepage or wet areas).

Photographs should be taken during the inspection. Many of the problems which a dam may develop do not happen over night but can take months or years to become obvious. By comparing photographs from previous inspections to the present, many of the subtle changes in a dam’s condition can be noted. Potential problems can be obscured by the excessive growth of vegetation.
Table 4 - Suggested Surveillance Schedule

Below is a summary of the most common problems associated with small dams and a suggested time for inspection.

<table>
<thead>
<tr>
<th>Location</th>
<th>Problem</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream slope</td>
<td>Slope failure.</td>
<td>After rapid drawdown.</td>
</tr>
<tr>
<td></td>
<td>Displacement of slope protection.</td>
<td>After severe wind storms, icing or heavy rain.</td>
</tr>
<tr>
<td></td>
<td>Tree or shrub growth.</td>
<td>Year round.</td>
</tr>
<tr>
<td>Crest</td>
<td>Settlement.</td>
<td>After heavy rain.</td>
</tr>
<tr>
<td></td>
<td>Rutting.</td>
<td>Autumn.</td>
</tr>
<tr>
<td></td>
<td>Tree and shrub growth.</td>
<td>Year round.</td>
</tr>
<tr>
<td>Downstream slope</td>
<td>Seepage.</td>
<td>When reservoir is at Full Supply Level (F.S.L.)</td>
</tr>
<tr>
<td></td>
<td>Slope failure.</td>
<td>When seepage is evident downstream slope.</td>
</tr>
<tr>
<td></td>
<td>Rodent burrows.</td>
<td>Spring and fall.</td>
</tr>
<tr>
<td></td>
<td>Tree and shrub growth.</td>
<td>Year round.</td>
</tr>
<tr>
<td>Downstream toe</td>
<td>Seepage.</td>
<td>During high reservoir levels.</td>
</tr>
<tr>
<td></td>
<td>Bulging - indicating a slide.</td>
<td>After high reservoir levels.</td>
</tr>
<tr>
<td></td>
<td>Tree and shrub growth.</td>
<td>Year round.</td>
</tr>
</tbody>
</table>
Table 5 - Minimum Suggested Inspection and Surveillance Frequency

See Schedule 2, of the Dam Safety Regulation
5. Inspection of Embankment Dams

The external surfaces of an embankment dam can often provide clues to the behaviour of the interior of the structure. For this reason, a thorough examination of all exposed surfaces of the dam should be made.

The embankment should be carefully examined for any evidence of displacement, cracks, sinkholes, springs, and wet spots. Any of these conditions may be in a developing mode and, if they worsen and are not corrected, ultimately could lead to failure of the embankment.

The following are the main components of an embankment dam and some inspection tips:

a) The Crest
The crest is generally the main access to most dams. It is often used as a crossing for farm equipment, for livestock, for recreational vehicles and as a public access road. This traffic as well as excessive vegetation can obscure the signs of any problems which may be present. For this reason, very close attention must be paid to the crest during an inspection (see the Self Help Guide in Section 7). The crest should be inspected for the following most threatening deficiencies:

**LONGITUDINAL CRACKING** which can indicate localized instability, differential settlement, and/or movement between adjacent sections of the embankment. (see figure No. 12)

**TRANSVERSE CRACKING** which can indicate differential settlement or movement between adjacent segments of the dam. (see figure No. 11)

**MISALIGNMENT** which can indicate relative movement between adjacent portions of the dam in directions perpendicular to the axis of the dam.

Other deficiencies which should be inspected for are:
- Narrowing of crest width from erosion.
- Low areas caused by erosion or settlement (this is of concern because it reduces the freeboard).
- Ruts caused by vehicle or livestock traffic which allow water to pond.
- Animal burrowing.
- Excessive vegetation
- Sinkholes or any unexplained hole or cavity which might indicate internal erosion.

b) Upstream Slope
If the reservoir is maintained at its Full Supply Level (FSL), most of the upstream slope of the dam will be submerged. In this case, only the upstream slope above the water level can be inspected. The inspection of the rest of the slope should be carried out when the water level is low.

The upstream slope should be inspected for the following deficiencies:
- Slope erosion from wave action.
- Displacement or loss of rip rap.
SLIDES are easily spotted and require immediate evaluation by a qualified Professional Engineer and notification of your Provincial Dam Safety Officer. There are, however, early warning signs of a slide. A bulge in the embankment or vertical displacement at a crack in the embankment may indicate sliding.

SEEPAGE occurs at all dams in varying degrees. The most potentially dangerous condition is the appearance of seepage on the downstream face above the toe of the dam. Seepage on the downstream slope can lead to a slide or failure of the dam by internal erosion (piping). The degree of concentration and the rate of flow should be noted. The presence of fines (silt) in the seepage flow, making it appear dirty or murky, would indicate the possibility of internal erosion (piping).

Other deficiencies which should be inspected for are:
- Bulges on the lower areas of the slope which may indicate instability.
- Depressions or unexplained holes which might indicate internal erosion (piping).
- Excess vegetation, especially trees which can severely weaken the slope.
- Erosion caused by runoff.
- Rutting caused by livestock traffic.
- Animal burrowing.
- Standing or ponded water at the downstream toe which can cause slope instability.

d) Abutment
Abutments should be inspected for the following deficiencies:
- Seepage, especially at the abutment/embankment contact zone (called groins).
- Erosion of the abutment/embankment contact.
- Any other signs of abutment instability such as cracking or material displacement.

e) Downstream Toe
This area includes the area immediately below the dam up to and including the toe. The main problems or signs of problems which can develop in this area are seepage related. For example:
- Wet, marshy ground or standing water.
- Active sand boils (the ejection of sand and water resulting from piping).
- Seepage areas (these should be marked and their
6. Inspection of Concrete Dams
Concrete dams encompass a variety of structures which include gravity, slab and buttress, multiple arch, and single arch dams. Masonry dams may be considered as a gravity structure with many joints. Regardless of the type, all dams are subject to the same basic considerations with respect to safety.

Concrete dams fail for reasons different than earth dams. Several of these more serious problems are discussed below:

**STRUCTURAL CRACKS**
Cracks caused by overstressing of portions of the dam and result from inadequate design, poor construction techniques, or faulty materials. Structural cracks are often irregular, meaning they run at an angle to the major axes of the dam and may exhibit abrupt changes in direction. These cracks also have noticeable radial, transverse, or vertical displacement.

**FOUNDATION or ABUTMENT WEAKNESS**
Concrete dams transfer substantial load to the abutments and foundation. Although the concrete of the dam may endure, the natural terrain may crack, crumble, or move in a massive slide. If this occurs, support for the dam is lost, causing it to fail. Impending failure of the foundation or abutments is difficult to detect because initial movements are often very small.

**DETERIORATION due to ALKALI-AGGREGATE REACTION**
Severe deterioration can result from a chemical reaction between alkali present in cements and certain forms of silica present in some aggregates. This chemical reaction produces by-products in the form of silica gels which cause expansion and loss of strength within the concrete.

**Note:** It is emphasized that, should any of the above conditions be discovered during an inspection, the owner should contact the Provincial Dam Safety Officer in your region immediately. The services of a Professional Engineering Consultant may be required.

Other deficiencies which should be inspected for on a concrete dam are:
- Concrete deterioration
- Masonry deterioration
- Surface defects
- Displacement
- Misalignment
- Differential movement
- Leakage and seepage

7. Inspection of Appurtenant Works
The appurtenant works are structures or machinery that are auxiliary to dams which are built to operate and/or maintain dams. Appurtenant works include; outlets, spillways, gates, powerhouses, tunnels etc. The following are inspection tips for some of the appurtenant works:

**a) Spillway**
The main function of a spillway is to provide a safe evacuation route for excess water that has entered the reservoir after a large storm or rapid snow-melt. If the spillway is of inadequate size the dam can overtop. Overtopping is the main cause of dam failure. Defects in the spillway or in its design may cause the dam to fail by rapid erosion produced by floodwater going over the crest. A properly designed and maintained spillway provides adequate freeboard to account for infrequent rain storms that may raise the level of the reservoir above the designed full supply level and still account for wave run up on the upstream slope without overtopping the dam.

There are four major types of problems that can prevent a spillway from functioning properly. As soon as any of these problems is identified, remedial steps must be taken in order to correct the defect.

**Obstruction** - The spillway channel may be obstructed by excessive growth of grass and weeds, thick brush, trees, debris, beaver dams, snowdrifts, or landslide deposits. An obstructed spillway will
have a substantially reduced discharge capacity and can create serious problems such as overtopping.

Grass is usually not considered as an obstruction, however, tall weeds and brush should be periodically cleared and trees removed as soon as they are noticed. Brush and debris can be entangled with trees to form an effective obstruction. When this happens, an even and smooth flow pattern cannot be maintained. Consequently, flow capacity of the spillway will be reduced.

Any substantial amount of material deposited in the spillway channel from sloughing, landslide above the channel, or sediment transport into the area must be immediately removed. Unstable slopes above a spillway channel should be stabilized to prevent a slide from blocking the channel.

Excessive debris collected by a log-boom may cause the log-boom to break, obstructing the spillway. The log-boom should be cleared of debris periodically.

Lack of Erosion Protection - When a large storm occurs, the spillway is expected to carry a large amount of water for many hours. Severe erosion damage or complete washout could result if the spillway lacks the ability to resist erosion. If the spillway is excavated through rock or lined with concrete, erosion is usually not a concern. But if the spillway is excavated in sandy, deteriorated granite, clay, or silt deposits, erosion protection is very important. Generally, resistance to erosion can be increased if the spillway channel has a mild slope, or if it is covered with grass or armoured with riprap.

Deterioration - A spillway cannot be expected to perform properly if it has undergone deterioration. Deterioration includes collapse of side slopes, weathering of material, disintegration of riprap, breakdown of concrete lining, erosion of approach section, sloughing of chute channel, excessive siltation of 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.

Cracks - Cracks in concrete lining are commonly encountered in the spillway channel. The cracks may be caused by uneven foundation settlement, slab displacement, or excessive earth or water pressure. Large cracks will allow water to wash out fine materials below or behind the concrete slab, causing erosion and leading to more cracks. An extensive crack can cause the concrete slab to be severely displaced. Consequently, the slab may be dislodged and washed away by the flow.

b) Outlet

Outlets come in a range of designs, sizes, materials and types of control (see Figure 14). Most control mechanisms and conduits are usually submerged and not easily accessible for inspection and maintenance. For this reason they are often neglected and serious problems may develop and go unnoticed. These problems can range from the control works becoming inoperable to the conduit deteriorating to the point where the embankment can fail (see Figures 15 and 16).

Proper inspection of the outlet usually requires advance planning to allow outflows to be shut off and inundated areas to be pumped out. Inspection can then usually determine if a problem exists with the outlet. If the conduit
is 1.0 m or greater in diameter, an internal inspection is highly recommended.

Note: Internal inspection of an outlet pipe is possible down to approximately 0.6 metres diameter. Most outlets are considered a confined space and therefore are hazardous. The Workers’ Compensation Board of British Columbia’s Industrial Health and Safety Regulations section on ‘Entry into a confined space’ must be followed.

Outlet works should be inspected for the following deficiencies:

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

Note: In most cases services of a qualified Professional Engineering Consultant will be required to recommend corrective action when these problems are found.

c) Gates

The operability of a dam’s outlet gates is essential to the safe and satisfactory operation of the dam. On reservoirs used for recreation, fish propagation, or other uses for which release of water is not required, an operable outlet, as with all dams, provides the only means for the emergency drawdown of the reservoir, thereby being essential to the safety of the dam.

The main deficiencies to look for on gates are as follows:

- Lack of readily accessible operating controls.
- Rusted or non-lubricated valve stem threads.
- Debris lodged in the intake.
- Vandalism of the gate controls.
- Ice damage.

d) Signs/Signage

For some dam owners in B.C. there is a requirement under the Dam Safety Regulation to post signs indicating 24 hour emergency contact information should a problem at a dam be observed. The purpose of these signs is to help ensure that there is a minimum of delay in safeguarding the dam and the area downstream.

These Regulations specify such things as size of the sign, size of lettering on the sign etc. The main deficiencies to look for are the effects of vandalism, readability, overgrowth by foliage and out of date text and contact numbers.

8. Summary

All Formal Inspection Reports should be kept by the dam owner as an historical record of the performance of the dam. Depending on the complexity of the dam, the consequence classification of the dam and the requirements of the Dam Safety Officer, a completed copy of the Dam Inspection Checklist, located in Section 8, may be satisfactory. Based on the consequence classification, copies of these reports may be required by the Dam Safety Officer.

Note: Evaluation of the conditions downstream of the dam must be undertaken at the same time as the formal inspection to ensure the consequence classification of the dam has not changed. Any changes must be reported to the Dam Safety Officer.

Two copies of the Dam Inspection Checklist are located in Section 8. This checklist can also be used as a guide during routine surveillance inspections. Additional copies should be photocopied by yourself or obtained from your local Dam Safety Officer.

Further information on the frequency of dam inspections, the recording and reporting requirements of these inspections and the methods of inspection and repair can be obtained from your Dam Safety Officer.

The services of a qualified Professional Engineering Consultant may be required for serious problems.
Best protection from ice and water damage. The downstream side of the gate can be inspected in the dry. By blocking the inlet, the well and conduit can be drained for maintenance and repairs.

May be difficult to service unless it is installed in a dry well. Conduit upstream of valve is under constant pressure from reservoir head.

Slidegate and control may be damaged by ice, leaving system inoperable.

Slidegate, control and catwalk may be damaged by ice, leaving system inoperable. Catwalk requires additional maintenance to remain in a safe usable condition.

Entire conduit is under constant pressure from reservoir head. This design would not be allowed on new or replacement outlets. See potential failure scenario Figure No. 16, page 31.

Figure No. 14 - Most Common Types of Low Level Outlet Controls
Figure No. 15 - Development of a Sinkhole and Failure Resulting from a Hole or Joint Separation in the Conduit.
A - Hole develops in conduit with downstream valve which is under constant pressure from reservoir head.

B - Hole enlarges allowing increased flow and a piping failure begins.

C - Reservoir drains through the conduit.

Figure No. 16 - Development of a Piping Failure Resulting from a Hole in a Conduit with a Downstream Valve.
1. Commitment to Maintenance
One of the responsibilities of owning and operating a dam, regardless of its size, is the commitment to maintain it. When minor problems are identified during an inspection, they should be dealt with as quickly as possible. A program of regular preventative maintenance will stop many of these problems from developing in the first place. If a change or deterioration of the conditions of the dam is noted in its early stages, repairs to remedy the situation can often be completed with minimal expense. If the problem is not detected or if it is ignored, repairs may become complex and very expensive. If a dam is left to deteriorate, failure will eventually result.

2. Embankment Dam Maintenance
Earthfill structures require maintenance work directed at controlling seepage and erosion, in order to prevent deterioration of structures and development of seepage paths.
Annual or long-term maintenance programs for earthfill structures may include regular control of vegetation and burrowing animals, rip-rap and crest maintenance and repair, slope stabilization, drainage system maintenance, removal of upstream debris, and maintenance of instrumentation.

a) Vegetation Control
The first maintenance requirement is to keep all portions of the dam clear of unwanted vegetative growth. (see Figures No. 17 & 18 for before and after views). Excessive growth is harmful in the following ways:
• It can obscure the view of the embankment and prevent a thorough inspection for possible cracks or other evidence of problems on the dam.
• Large trees could be uprooted during a storm and the resulting large hole left by the root system could lead to breaching of the dam.
• Some root systems can decay and rot, providing a tunnel for water to pass through (called piping).
• Root systems can cause the uplift of concrete slabs or structures.
• Weeds can discourage the growth of desirable grasses.

b) Crest and Slope Stability
Deterioration of the surface of an earth dam may occur for a number of reasons. For example, wave action may cut scarps into the upstream slope, vehicles may cause ruts in the crest, or runoff waters may leave erosion gullies on the downstream slope. Damage of this nature must be repaired on a continuing basis.

Conditions such as embankment slides, structural cracking, sand boils, and sinkholes threaten the safety of the dam and require that you notify your Dam Safety Officer. The services of a Professional Engineering Consultant may be required.

c) Burrowing Animal Control
Rodents can cause a variety of different types of damage to a dam. The type of treatment depends upon the nature of the damage. Further information on rodent control and methods of repairing rodent damage can be obtained from your Dam Safety Officer. Permits may be required from the Wildlife Branch of the Provincial Government before undertaking rodent control.

3. Concrete Dam Maintenance
Generally speaking, concrete is a reasonably durable material. However, because of the environment in which it is used, concrete does deteriorate over the years, and this process is accelerated by exposure to extreme weather conditions. The most common form of failure is the breakdown of the surface layers of concrete as evidenced by the scaling, surface cracking and pitting which becomes very noticeable.
A more serious form of failure is indicated by the appearance of structural cracking in the concrete. The most common cause for this type of failure is the increase in stress that the concrete is subjected to and usually results from the uneven settlement of the structure or from unequal or excessive earth pressures against the
Note: Large structural cracks threaten the safety of the dam and require that you contact your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required.

Annual or long-term maintenance programs for concrete structures should include, but not be limited to, regular cleaning of drains and drainage systems, maintenance of sealing systems, pumping equipment, monitoring equipment and instrumentation required to assure the safety of the structure.

4. Appurtenant Works Maintenance

Maintenance requirements may apply to all appurtenant works, including mechanical and electrical components, which are essential to dam safety. The following are a few of the appurtenant works that require maintenance:

- spillways,
- outlets,
- gates,
- hoists,
- stoplogs,
- log-booms,
- normal and emergency lighting and
- pumps.

a) Spillway Maintenance

A spillway should always be kept free of obstruction, have the ability to resist erosion, and be protected from deterioration. Removal of material blocking the spillway is necessary to allow unrestricted outflow. Some routine maintenance items may include:

- remove floating debris from the reservoir (particularly around the spillway entrance) and dispose of it away from the dam and above the flood water level,
- repair or replace any substandard part of the debris containment boom (log-boom), i.e. boom sticks (logs), chains, cables and anchors,
- remove any soil, sediment, or rock fall that has entered the spillway channel,
- remove any beaver dams.

b) Outlet Gate Maintenance

The simplest procedure which can be used to insure the
continued operability of the outlet gates is to cycle all gates through their full operating range at least once, preferably twice annually. As cycling of gates under full reservoir head could result in large outlet discharges, it is recommended that gate cycling be scheduled during periods of low storage. If this cannot be done, cycling should be done during periods of low stream flows. If large releases are anticipated, outlet testing should be done only after coordinating releases with Dam Safety Officers and notification of downstream residents and water users. Notification should also be given to the local fisheries officer.

Cycling of the gates prevents the buildup of rust on contact surfaces of the operating mechanism and the possible seizure of the operating mechanism as contact surfaces rust together.

5. Summary

It should be emphasized that a dam and reservoir represent not only a potential public hazard, but also a substantial investment. The dam’s owner can identify any changes in previously noted conditions that indicate a safety problem. A conscientious annual maintenance program will address and control most potential problems.

Maintenance solutions for specific problems are outlined in the Self Help Guide in Section 7, under ‘Recommended Action’. Some routine maintenance items may include:

- Removing debris
- Re-grading the crest and/or access road
- Adding riprap when required
- Sealing joints in concrete facings
- Cleaning drain pipes and outfalls
- Maintaining protection for monitoring points
- Maintaining security for operating equipment

Further information on maintenance can be obtained from your Dam Safety Officer.

Note: When operating the outlet, excessive force should not be needed nor should it be applied to either raise or lower the gate. Most hoisting mechanisms are designed to operate satisfactorily with a maximum force of 40 pounds on the operating handle or wheel. If excessive force is needed, problems may have developed with the outlet installation which are causing binding in the mechanical system. The application of excessive force may irreversibly bind the gate or damage the outlet works.

Note: Contact your Dam Safety Officer if you encounter conditions which may threaten the safety of the dam such as embankment slides, structural cracking, boils and sinkholes. The services of a qualified Professional Engineering Consultant may be required.

Figure No. 19 - Intake Control Access Structure Failure
1. Operation, Maintenance and Surveillance (OM&S) Plan

The objective in formulating an operation, maintenance and surveillance (inspection) plan is to provide the greatest possible assurance of the safety of the dam and continuous operation of the reservoir.

An effective plan provides all the information and instruction needed to allow an inexperienced person to perform all actions required to operate the dam safely and in the case of an emergency to provide protection and/or notification to the public downstream.

Among the items addressed are the operation of the outlet gate and the spillway, the surveillance (inspection) schedule of the dam, the monitoring of the dam’s performance, the recording and interpreting of the results of the surveillance and monitoring, the development of a Dam Emergency Plan and the performance of all required maintenance.

By creating and using an OM & S plan, the dam owner can expect these benefits:
- Assure the safety of the dam and the continuous operation of the reservoir,
- Operating the water usage in the best manner possible,
- Minimizing the need for costly repairs,
- Extending the useful life of the structure.

A simplified guide for preparing an OM&S plan is located in Section 8 to aid the dam owner in the development of their plan.

2. Assembling an OM&S Plan

Assembling the required information and writing the OM&S plan is the responsibility of the dam owner. The OMS plan should include the following (if available):

a) Information

Maps, plans, and other sources should be reviewed for dimensions and descriptions that will provide a clear picture of the location, make-up, and function of each part of the dam. Especially important are:
- The water licence number along with a copy of the licence,
- 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,
- Location and detail of monitoring points,
- Capacity table for the reservoir,
- Discharge table for the outlet and spillway,
- Location and capacity of inflow and outflow structures,
- How is the dam and reservoir operated i.e. fall and winter drawdown, minimum and maximum releases,
- Expected inflows i.e. low flow, design flood inflow,
- Watershed considerations upstream and downstream of dam,
- Record of past inspections, monitoring, repairs, and operating problems,
- Photographs, taken annually and kept on file for comparison and reference.

b) Outlet And Reservoir Operating Instructions

A clear step-by-step set of instructions for operating the outlet system should be drawn up. 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 should be listed.

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

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

c) Surveillance (Inspections)
Frequent periodic surveillance is essential in efforts to assure the safety of the dam and to identify areas requiring maintenance before major problems develop. The OM&S plan should identify any areas requiring special or more frequent surveillance. Using the dam inspection checklist found in Section 8 will allow inspection findings to be assessed more clearly.

d) Monitoring Instructions
The benefits of monitoring the dam can only be achieved if the observations are recorded in an orderly way, then put into a form that will allow the data to be seen as a performance record.
A site plan identifying each monitoring point for the dam is required. Each of these monitoring points plus any seepage or other areas needing special attention should be kept clear of obscuring growth and be permanently marked so they can be found during surveillance. Instruction on how to make and record each measurement or observation must be provided.

e) Maintenance Instructions
Any special instructions for performing periodic maintenance should be given in detail. This will allow new personnel to understand the task and experienced personnel to make sure they have completed the work properly.
All required maintenance work should be identified and listed.

f) Schedule
Once the various required tasks have been identified, a schedule showing the frequency for each task needs to be drawn up which meets or exceeds the requirements listed in "Schedule 2" of the Dam Safety Regulation.

Note: The Consequence classification of all dams have been determined by the Dam Safety Officer.
Any submission for revision must be made to the Dam Safety Officer.

Further information on dam consequence classification and scheduling of inspection, maintenance and monitoring can be obtained from your Dam Safety Officer.

g) Record Keeping
It is recommended that all records relating to the dam such as the water rights licence, “As Constructed” plans, inspection records, photographs, correspondence, etc., be kept together. All ongoing repairs should be fully described and this information added to the record. This will provide a history of the dam for future use.

h) Communication
A list of the individuals involved in the operation and administration of the dam should be included in the OM&S plan along with identification of each person’s involvement. This will help promote the required communication and a cooperative relationship with those individuals.
By conscientiously following a well-thought-out OMS plan the dam owner can expect:
• Maximum assurance of a safe dam;
• Maximum assurance of uninterrupted service for the dam and reservoir;
• Reduced maintenance cost; and
• An extended useful life for the dam.

j) Dam Emergency Plan

If a dam is designed according to sound engineering principles and is well constructed and maintained, the possibility of failure is extremely remote. If, however, potential failure of a dam poses a hazard to life and property, the dam owner must have an emergency preparedness plan to deal with any potential problems. This plan should address the following:
• Who will be affected and how can they be contacted?

Persons immediately downstream should be notified as well as local authorities so they can co-ordinate evacuation plans if necessary.

A template for preparing a Dam Emergency Plan is provided in the Dam Safety in BC website. Contact your Dam Safety Officer for more information.

3. Summary

A Guide for Preparing an OM&S plan is located in Section 8 to aid the dam owner in the development of their plan.

This OM&S Plan must be reviewed by the Dam Owner annually to ensure contact names and phone numbers are kept up to date. All holders of the OM&S Plan must be sent copies of any revisions. See the table in Schedule 2 of the Dam Safety Regulation for required frequency of all activities under the regulation including the Dam Emergency Plan.
Table 6 - Consequence Classification Guide

See Schedule 1, of the Dam Safety Regulation
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**DEFICIENCY CHECKLIST**

If you find deficiencies with any component of your dam, use the following table to guide you to the relevant section of the *SELF-HELP GUIDE* in the Appendix of the Inspection and Maintenance of Small Dams booklet.

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</tbody>
</table>
1. Reservoir Problems

1 - Slides and Sloughs

**Causes:**
1. Ice action and wave erosion which creates vertical slopes.
2. Steep slopes left unsupported by erosion.
3. Toe of slope becomes saturated by the reservoir.

**Concerns:**
1. The slides or slough area may endanger the embankment.
2. Waves caused by a slide may endanger the embankment.

**Recommended Action:**
1. Monitor the area and notify your Dam Safety Officer if the embankment is threatened. The services of a qualified Professional Engineering Consultant may be required.

2 - Floating Debris

**Causes:**
1. Beaver activity.
2. Heavy runoff.

**Concern:**
1. Debris may block spillway or outlet.

**Recommended Action:**
1. Install trash racks or floating booms where necessary and clean them as required.

3 - Beaver Activity

**Cause:**
1. A favourable habitat.

**Concern:**
1. Beaver activity may block spillway or outlet causing water to rise and overtop the embankment.

**Recommended Action:**
1. Remove the beaver dam.
2. Contact the Wildlife Branch of the Provincial Government re: relocating the beaver.
2. Crest Problems

1 - Excessive Vegetation

Causes:
1. Lack of maintenance.
2. Neglect.

Concerns:
1. Prevents a thorough inspection.
2. Obscures any problems which might exist.
3. Root system can weaken the embankment and result in a failure.
4. Prevents easy access.
5. Provides a habitat for unwanted burrowing animals.

Recommended Action
1. Remove excessive vegetation and root system
2. Remove cuttings and debris from embankment area.
3. The embankment should be seeded with an appropriate grass.
4. Prevent or remove re-occurring growth as part of a regular maintenance program.

2 - Rodent Activity

Cause:
1. Burrowing animals.

Concerns:
1. Can weaken the embankment.
2. Can cause a piping failure.

Recommended Action:
1. Control rodents.
2. Remove favourable habitat conditions.
3. Backfill rodent burrows with compacted fill or a pumped grout.

3 - Ruts Along Crest

Causes:
1. Heavy vehicles, farm equipment or livestock traffic.
2. Lack of maintenance or inadequate crest surfacing.

Concerns:
1. Allows continued rutting.
2. Allows standing water to collect and saturate the crest.
3. Vehicles crossing the crest can get stuck causing further damage.

Recommended Action:
1. Regrade and recompact crest to original elevation with a camber to the upstream slope which will encourage proper drainage of runoff back into the reservoir.
2. Provide surface resistant to rutting such as placement of crushed gravel surfacing.
2. Crest Problems (cont.)

4 - Drying Cracks

**Cause:**
1. Crest material expands and contracts with alternating wet and dry weather.

**Concern:**
1. Provides an entrance point for surface water which can saturate the crest material.

**Recommended Action:**
1. Re-grade or tight blade the crest if necessary.

5 - Longitudinal Cracking

**Causes:**
1. Uneven settlement within the embankment or foundation.
2. Initial stage of a slope failure or embankment slide.

**Concerns:**
1. Results in an area of high instability.
2. Can lead to future movements or failure (see Figure 8, page 17).
3. Provides an entrance point for surface water which can promote movement.
4. Can reduce the effective crest width.

**Recommended Action:**
1. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determine the cause and recommend a plan of action.
2. The crack(s) should be monitored.
3. A lower reservoir operating level may be required.

6 - Transverse Cracking

**Causes:**
1. Uneven movement between two adjacent segments of the embankment.
2. Instability of the embankment or foundation.

**Concerns:**
1. Provides an entry point for surface water.
2. Creates an area of structural weakness which could result in further movements or failure.
3. May create a seepage path from the reservoir and a potential piping failure (see Figure 9, page 18).

**Recommended Action:**
1. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determine the cause and recommend a plan of action.
2. The crack(s) should be excavated and back-filled with compacted material to prevent seepage.
3. Area should be closely monitored for future movement.
2. **Crest Problems** (cont.)

7 - **Low Area on the Crest**

**Causes:**
1. Excessive settlement of the embankment material or the foundation.
2. Internal erosion of the embankment material.
3. Prolonged erosion from wind or water.
4. Poor construction practices.

**Concerns:**
1. Reduced freeboard for safe routing of floodwater.
2. Floodwater may overtop the embankment in the low area rather than passing through the spillway.

**Recommended Action:**
1. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determine the cause and recommend a plan of action.

8 - **Sinkhole on the Crest**

**Causes:**
1. Burrowing animals.
2. Internal erosion from seepage piping or a hole in the conduit.

**Concerns:**
1. Sloughing/caving can occur in the sinkhole leading to embankment instability and development of a low area.
2. Provides an entrance point for surface water.
3. Depending on size and depth, may lead to a failure.

**Recommended Action:**
1. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determine the cause and recommend a plan of action.
3. Upstream Slope Problems

1 - Erosion (Beaching and Scarps)

**Causes:**
1. Wave or ice action.
2. Local settlement.
3. Inadequate erosion protection.

**Concerns:**
1. Continued erosion can reduce crest width and height leading to a possible overtopping.
2. May cause increased seepage.

**Recommended Action:**
1. Regrade the upstream slope to the original design grade.
2. Provide adequate slope protection.

2 - Displaced and Broken Down Riprap

**Causes:**
1. Wave or ice action.
2. Poor quality riprap.
3. Same size rock (improperly designed), leaving gaps which allow waves to erode underlying material.

**Concerns:**
1. Allows increasing erosion which can reduce the width and height of the embankment.

**Recommended Action:**
1. Re-establish adequate slope protection with underlying filter bed.
2. Repair erosion damage with properly designed erosion protection.

3 - Burrowing Animal Activity

**Cause:**
1. A habitat which encourages beaver and muskrat activity.

**Concern:**
2. Burrowing can weaken the embankment and lead to its failure.

**Recommended Action:**
1. Remove the burrowing animals.
2. Compact the burrows with compacted fill or a pumped grout.
3. Remove the supporting habitat.
3. Upstream Slope Problems (cont.)

4 - Excessive Vegetation and Trees

Causes:
1. Neglect.
2. Poor maintenance procedures.

Concerns:
1. Can obscure serious problem which may exist.
2. Root systems can penetrate and weaken the embankment and create seepage paths.

Recommended Action:
1. Remove excessive vegetation.
2. Keep vegetation under control as part of a regular maintenance program.

5 - Large Cracks

Causes:
1. A foundation failure.
2. Localized instability.

Concerns:
1. Almost always precedes a slope failure or large scale settlement.

Recommended Action:
1. The reservoir should be drawn down.
2. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determine the cause and recommend a plan of action.

6 - Slide or Slump

Causes:
1. Foundation failure.
2. Too steep a slope.
3. A rapid draw down of the reservoir.

Concerns:
1. Can lead to a failure of the dam.
2. Slide debris can block low level outlets.

Recommended Action:
1. Draw the reservoir down.
2. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determine the cause and recommend a plan of action.
3. Upstream Slope Problems (cont.)

7 - Sinkhole

**Cause:**
1. Concentrated seepage begins to “pipe” embankment material through the dam. This loss of material causes the inlet of the “pipe” to collapse forming a sinkhole.

**Concern:**
1. Usually results in a piping failure.

**Recommended Action:**
1. Draw the reservoir down.
2. Look for other sinkholes and their exits.
3. Examine outflow for dirty water.
4. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determined the cause and recommend a plan of action.

4. Downstream Slope Problems

1 - Longitudinal Cracking

**Causes:**
1. Drying and shrinking of embankment material.
2. Settlement of embankment of foundation material.

**Concerns:**
1. Provides an entry point for surface water.
2. Causes embankment instability.
3. Can be an early warning of a slope failure, slide or slump.

**Recommended Action:**
1. Drying cracks should be sealed.
2. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determined the cause and recommend a plan of action.

2 - Slump / Slide

**Causes:**
1. Too steep a slope.
2. Loss of embankment material strength from settlement or excessive seepage.

**Concerns:**
1. Can cause additional slumps/slide.
2. Can lead to embankment failure.

**Recommended Action:**
1. Draw down the reservoir.
2. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determined the cause and recommend a plan of action.
4. Downstream Slope Problems (cont.)

3 - Wet Areas / Seepage

Causes:
1. Seepage through the embankment or under the foundation.
2. Surface water entering through cracks or animal burrows.

Concern:
1. Creates slope instability which can lead to a failure.
2. Indicates the possibility of internal erosion (piping).

Recommended action:
1. Monitor the area for a change in size.
2. Monitor seepage outflow, if any, for dirty water which would indicate internal erosion (piping).
3. If dirty water is seen notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determine the cause and recommend a plan of action.

4 - Cave in / Collapse

Causes:
1. Poor compaction during construction.
2. Internal erosion (piping) through the embankment or foundation.
3. Animal burrowing.

Concerns:
1. Can cause increased seepage.
2. Indicates a potential for failure.

Recommended action:
1. Monitor the area for change.
2. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determine the cause and recommend a plan of action.

5 - Erosion / Rutting

Causes:
1. Livestock traffic.
2. Surface runoff.
3. Poorly protected slope.

Concerns:
1. Encourages further erosion.

Recommended action:
1. Regrade slope and sow a cover crop.
2. Keep livestock off embankment.


5. Downstream Toe Problems

1 - Seepage Water Exiting as a Sand or Water Boil

Causes:
1. A concentrated seepage path or pipe has developed through the foundation.
2. A layer of sand or gravel in the foundation being charged by the reservoir.

Concern:
1. Dirty seepage water is an indication that piping may be occurring and may result in a piping failure of the foundation and ultimately the embankment.

Recommended Action:
1. The outflow should be examined for dirty water.
2. The area and flow should be monitored and the reservoir drawn down if flows increase.
3. Notify your Dam Safety Officer.
4. The services of a qualified Professional Engineering Consultant may be required.

2 - Standing / Ponded Water at the Downstream Toe

Causes:
1. Heavy seepage.
2. Surface runoff.
3. Poor drainage away from the toe.

Concerns:
1. Obscures source and makes flow rates difficult to estimate.
2. Saturates and destabilizes the downstream slope.
3. Can result in slope failure.

Recommended Action:
1. Provide and adequate drainage system to prevent ponding.
2. Identify source of water and consult a Professional Engineer if necessary.

6. Downstream Abutment Problems

1 - Wet Areas or Water Exiting from Downstream Abutment

Cause:
1. A seepage path or “pipe” passing around the embankment through the natural abutment material.

Concern:
1. May result in an abutment piping failure.

Recommended Action:
1. Monitor the area and flow for change and the presence of dirty water.
2. Notify your Dam Safety Officer.
3. The services of a qualified qualified Professional Engineering Consultant is required if the seepage flow increases and dirty water is present.
7. Low Level Outlet Problems

1 - Inoperable Low Level Outlet Control

Causes:
1. Deterioration of concrete. Excessive force applied to a jammed control stem.
2. Inadequate or broken stem guides. Lack of maintenance requiring excessive pressure to operate the gate.
3. Lack of maintenance causing guides to bind to stem and break when gate is jammed.
4. Corrosion, cavitation, impact from water borne debris.

Concerns:
1. Gate control becomes inoperable preventing a draw down of the reservoir, if required, and preventing passage of water for downstream uses.
2. If gate is jammed open, reservoir operating levels cannot be maintained and water is wasted.

Recommended Action:
1. Use of the outlet control should be minimized until all damaged components are repaired.
2. Institute a regular maintenance program to ensure control system is fully operable.

2 - Perforated Conduit

Causes:
1. Corrosion
2. Joint separation.

Concern:
1. May lead to serious internal erosion and a possible piping failure (see Figs. 16 and 17 on pp. 30 & 31).

Recommended Action:
1. Notify your Dam Safety Officer. The services of a qualified Professional Engineering Consultant may be required to determined the cause and recommend a plan of action.
8. Spillway Problems

1 - Eroded Channel / Slide

Causes:
1. Inadequate erosion protection.
2. Too steep a gradient.

Concerns:
1. Channel erosion deepens and generally works its way upstream.
2. Can result in the reservoir draining through the eroded channel.

Recommended Action:
1. Repair the eroded area with compacted fill.
2. Provide adequate erosion protection.
3. Regrade the channel if necessary.

2 - Blocked Channel

Causes:
1. Floating debris from the reservoir.
3. Man-made.

Concerns:
1. May restrict spillway channel flow causing the embankment to overtop.

Recommended Action:
1. Remove the blockage.
2. Prevent future blockages.
3. Install trash racks if necessary.

3 - Other Problems

There are many problems that can develop depending on the type of spillway and the materials it is constructed from. If the spillway develops problems which go unnoticed the embankment may be endangered.

Recommended action:
1. Ensure that the capacity of the spillway matches the design flood inflow.
2. Regularly inspect and maintain the spillway.
3. Remove any blockage of the spillway.
4. If uncertain about a particular problem, an engineer should be consulted.
Section 8
Attachments and Guides

1. For Further Information

2. Guide for Preparing an Operation, Maintenance and Surveillance

3. Guide for Preparing a Dam Emergency Plan
   See `Dam Emergency Plan` Template on the Dam Safety in BC website

4. Deficiency Checklist

5. Site Surveillance Checklist – Earthfill and Concrete

6. See “Formal Annual Inspection” Checklist on the Dam Safety in BC website
## FOR FURTHER INFORMATION

For further information or comments on this Dam Safety Guideline or to call your nearest Dam Safety Officer please refer to the list below:

<table>
<thead>
<tr>
<th>Location</th>
<th>Address</th>
<th>Phone</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kamloops</td>
<td>1259 Dalhousie Drive, Kamloops, BC V2C 5Z5</td>
<td>(250) 371-6200</td>
<td>(250) 371-6234</td>
</tr>
<tr>
<td>Surrey</td>
<td>Suite 200, 10470 153rd Street, Surrey, BC V3R 1E1</td>
<td>(604) 582-5200</td>
<td>(604) 930-7119</td>
</tr>
<tr>
<td>Nanaimo</td>
<td>2080A Labieux Road, Nanaimo, BC V9T 6J9</td>
<td>(250) 751-3100</td>
<td>(250) 751-7079</td>
</tr>
<tr>
<td>Penticton</td>
<td>102 Industrial Place, Penticton, BC V2A 7C8</td>
<td>(250) 490-8200</td>
<td>(250) 490-2231</td>
</tr>
<tr>
<td>Nelson</td>
<td>#401 333 Victoria Street, Nelson, BC V1L 4K3</td>
<td>(250) 354-6333</td>
<td>(250) 354-6332</td>
</tr>
<tr>
<td>Prince George</td>
<td>325 - 1011 4th Avenue, Prince George, BC V2L 3H9</td>
<td>(250) 565-6135</td>
<td>(250) 565-6629</td>
</tr>
</tbody>
</table>

Or for dams over 9 metres in height and/or to obtain additional information on the Dam Safety Program contact:

- Dam Safety
- Water Management Branch
- Provincial Government
- PO Box 9340 Stn Prov Govt
- Victoria, British Columbia V8W 9M1
- Phone: (250) 952-6790
- Fax: (250) 356-0605

24 HOUR EMERGENCY CONTACT - PROVINCIAL EMERGENCY PROGRAM (EMBC) - 1-800-663-3456
GUIDE FOR PREPARING AN OPERATION, MAINTENANCE AND 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:

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Phone #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.)


Page 2
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 Surveillance 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,
- All monitoring data,
- All repairs done, and,
GUIDE AND TEMPLATE FOR PREPARING A DAM EMERGENCY PLAN

Please use the “Guide and Template for Preparing a Dam Emergency Plan” that can be found in the Technical Resources section of the Dam Safety in BC website or contact your Dam Safety Officer.
## DEFICIENCY CHECKLIST

If you find deficiencies with any component of your dam, use the following table to guide you to the relevant section of the *SELF-HELP GUIDE* in the Appendix of the Inspection and Maintenance of Small Dams booklet.

<table>
<thead>
<tr>
<th>IS THERE ANY APPARENT...</th>
<th>YES</th>
<th>NO</th>
<th>IF YES THEN...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CRACKS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• embankment cracks on the crest?</td>
<td></td>
<td></td>
<td>sub-sections 2.4, 2.5 &amp; 2.6</td>
</tr>
<tr>
<td>• embankment cracks on the u/s slope?</td>
<td></td>
<td></td>
<td>sub-section 3.5</td>
</tr>
<tr>
<td>• embankment cracks on the d/s slope?</td>
<td></td>
<td></td>
<td>sub-section 4.1</td>
</tr>
<tr>
<td><strong>VEGETATION GROWTH AND DEBRIS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• excessive vegetation growth on the embankments?</td>
<td></td>
<td></td>
<td>sub-sections 2.1, 3.4 &amp; 5.2</td>
</tr>
<tr>
<td>• floating debris?</td>
<td></td>
<td></td>
<td>sub-section 1.2</td>
</tr>
<tr>
<td>• vegetation or debris blocking the spillway channel?</td>
<td></td>
<td></td>
<td>sub-section 8.2</td>
</tr>
<tr>
<td><strong>STRUCTURAL PROBLEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• settlement on the crest?</td>
<td></td>
<td></td>
<td>sub-section 2.7</td>
</tr>
<tr>
<td>• slough, slides or bulges on the u/s slope?</td>
<td></td>
<td></td>
<td>sub-section 3.6</td>
</tr>
<tr>
<td>• slough, slides or bulges on the d/s slope?</td>
<td></td>
<td></td>
<td>sub-section 4.2</td>
</tr>
<tr>
<td>• slough, slides or bulges on the reservoir shore?</td>
<td></td>
<td></td>
<td>sub-section 1.1</td>
</tr>
<tr>
<td>• slough, slide or erosion of spillway channel?</td>
<td></td>
<td></td>
<td>sub-section 8.1</td>
</tr>
<tr>
<td>• sinkhole on crest?</td>
<td></td>
<td></td>
<td>sub-section 2.8</td>
</tr>
<tr>
<td>• sinkhole on u/s slope?</td>
<td></td>
<td></td>
<td>sub-section 3.7</td>
</tr>
<tr>
<td>• sinkhole on d/s slope?</td>
<td></td>
<td></td>
<td>sub-section 4.4</td>
</tr>
<tr>
<td>• displaced or broken down riprap armor?</td>
<td></td>
<td></td>
<td>sub-section 3.2</td>
</tr>
<tr>
<td><strong>SEEPAGE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• wet areas or seepage on the d/s slope or toe?</td>
<td></td>
<td></td>
<td>sub-sections 4.3 &amp; 5.1</td>
</tr>
<tr>
<td>• ponded water at the downstream toe?</td>
<td></td>
<td></td>
<td>sub-section 5.2</td>
</tr>
<tr>
<td>• wet areas or seepage along d/s abutments?</td>
<td></td>
<td></td>
<td>sub-section 6.1</td>
</tr>
<tr>
<td><strong>ANIMAL ACTIVITY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• signs of livestock traffic across dam embankment?</td>
<td></td>
<td></td>
<td>sub-section 4.5</td>
</tr>
<tr>
<td>• rodent burrows in dam embankment?</td>
<td></td>
<td></td>
<td>sub-sections 2.2 &amp; 3.3</td>
</tr>
<tr>
<td>• beaver dams in reservoir or across spillway channel?</td>
<td></td>
<td></td>
<td>sub-section 1.3</td>
</tr>
<tr>
<td><strong>OUTLET PROBLEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• outlet operating problems?</td>
<td></td>
<td></td>
<td>sub-section 7.1</td>
</tr>
<tr>
<td>• deterioration of the outlet conduit?</td>
<td></td>
<td></td>
<td>sub-section 7.2</td>
</tr>
<tr>
<td><strong>SPILLWAY PROBLEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• spillway blockage?</td>
<td></td>
<td></td>
<td>sub-section 8.3</td>
</tr>
<tr>
<td>• channel blockage?</td>
<td></td>
<td></td>
<td>sub-section 8.2</td>
</tr>
<tr>
<td>• inadequate capacity?</td>
<td></td>
<td></td>
<td>sub-section 8.3</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>EMBANKMENT</th>
<th>OUTLET</th>
<th>SPILLWAY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. U/S Slope</td>
<td>Y N</td>
<td>1. Outlet Pipe</td>
</tr>
<tr>
<td>2. Crest</td>
<td>Y N</td>
<td>2. Energy Dissipater</td>
</tr>
<tr>
<td>5. Seepage Weirs</td>
<td>Y N</td>
<td>5. Outlet Channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7. Outlet Controls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8. Gates</td>
</tr>
</tbody>
</table>

Were any of the following POTENTIAL PROBLEM INDICATORS found?

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>EMBANKMENT</th>
<th>OUTLET</th>
<th>SPILLWAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Seepage</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td>b) External Erosion</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td>c) Cracks</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td>d) Settlement</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td>e) Sloughing / Slides</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td>f) Animal Activity</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td>g) Excessive Growth</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td>h) Excessive Debris</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>CONCRETE STRUCTURE</th>
<th>OUTLET</th>
<th>SPILLWAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Alignment</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>2. Joint Filler</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>3. Concrete Condition</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>4. Drains</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>5. Public safety signs</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>1. Outlet Pipe</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>2. Energy Dissipater</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>3. Stilling Basin</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>4. Drains</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>5. Outlet Channel</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>6. Measuring Weir</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>7. Outlet Controls</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
<tr>
<td>8. Gates</td>
<td>Y  N</td>
<td>Y  N</td>
</tr>
</tbody>
</table>

Were any of the following POTENTIAL PROBLEM INDICATORS found?

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>CONCRETE STRUCTURE</th>
<th>OUTLET</th>
<th>SPILLWAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Seepage</td>
<td>YES  NO</td>
<td>YES  NO</td>
<td>YES  NO</td>
</tr>
<tr>
<td>b) External Erosion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Cracks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Settlement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e) Horizontal Movement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) Excessive Debris</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g) Vegetation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
Formal Annual Inspection Form Check Sheet

Please use the “Formal Annual Inspection Form” that can be found in the Technical Resources section of the [Dam Safety in BC](https://www.dam safetyinbc.ca) website or contact your Dam Safety Officer. The form is designed to be modified to suit all types and sizes of dams. For example, the sections for Earth Fill Dams or Concrete Dams should be removed depending on what type of dam it is. For a smaller dam, an annual formal inspection form can be created from a site surveillance form check sheet. Regardless of the type of form used, a formal inspection report should be prepared and kept by the dam owner.