Inspection of Small Dams

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Alberta
ENVIRONMENT

Prepared by:

Dam Safety and Water Projects Branch
Water Management Division
Alberta Environmental Protection
8th Floor, Oxbridge Place
9820-106 Street
Edmonton, Alberta
T5K 2J6

Phone: (403)* 422-1355
Fax: (403)* 427-6334
Branch E-mail address: AEP-DamSafety.WaterProjects@gov.ab.ca

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1.0 Who is this booklet written for?

This booklet has been prepared by Alberta Environmental Protection, Dam Safety and Water Projects Branch, primarily for the private owner/operator who does not have professional engineers on staff. The booklet provides basic information and guidelines for performing visual inspections of small dams. The material provided will help the owner/operator to recognize and deal with potential problems that may develop with their structures.

Sections 1.0 to 7.0 cover the basics while Sections 8.0 and 11.0 provide details on inspecting and maintaining small dams. Section 12 is a self-help guide, complete with illustrations, to assist the owner/operator in dealing with specific problems. The Glossary at the back of the booklet provides definitions of the terms which are used throughout this booklet.

2.0 What is a Dam?

A dam is any barrier constructed for the purpose of storing water or water borne material. The term "Dam" may be used not only to describe the embankment but may also include all associated structures such as spillways, dykes, riparian and canal outlets. Drawing 1 (page 2) represents a typical plan, profile and cross section of a dam.

3.0 The need for Dam Safety

Dams and reservoirs create risks. The owner is responsible for:

- safely operating and maintaining the dam;
- giving appropriate warnings if the operation or failure of the dam could cause damage;
- compensating damage caused by the operation or failure of the dam.

By having a regular inspection program even for the smallest of dams, the owner benefits by:

- being able to recognize problems in their early stages and eliminating them before they become complex and expensive problems;
- minimizing risks and liability for downstream life or property.

Occasionally, problems can develop which are beyond the expertise of the owner/operator. In these instances, a professional engineer, experienced in the design of dams, should be hired to evaluate the situation and recommend a course of action. In some cases, financial assistance and/or engineering expertise may be available through programs offered by the Government of Alberta, the Federal Government's Prairie Farm Rehabilitation Administration (P.F.R.A.) or private conservation organizations.

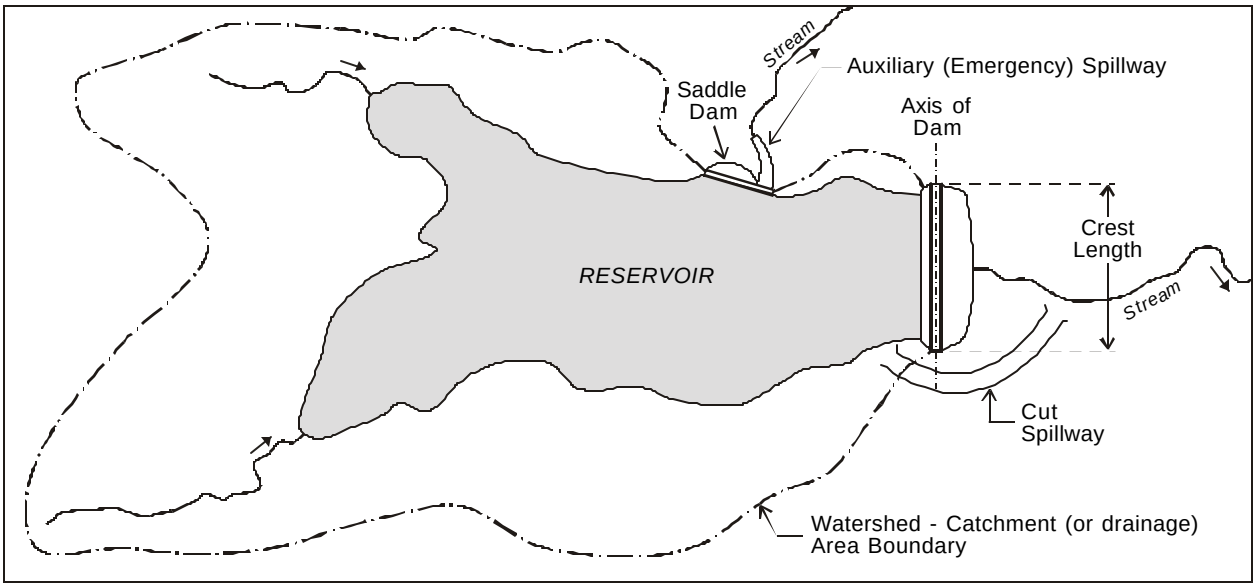
Photo No. 1 (DSB 8609-19)
Mound Red Park Reservoir – 1986

Photo No. 2 (DSB 9051-18)
Mound Red Park Reservoir July, 1990

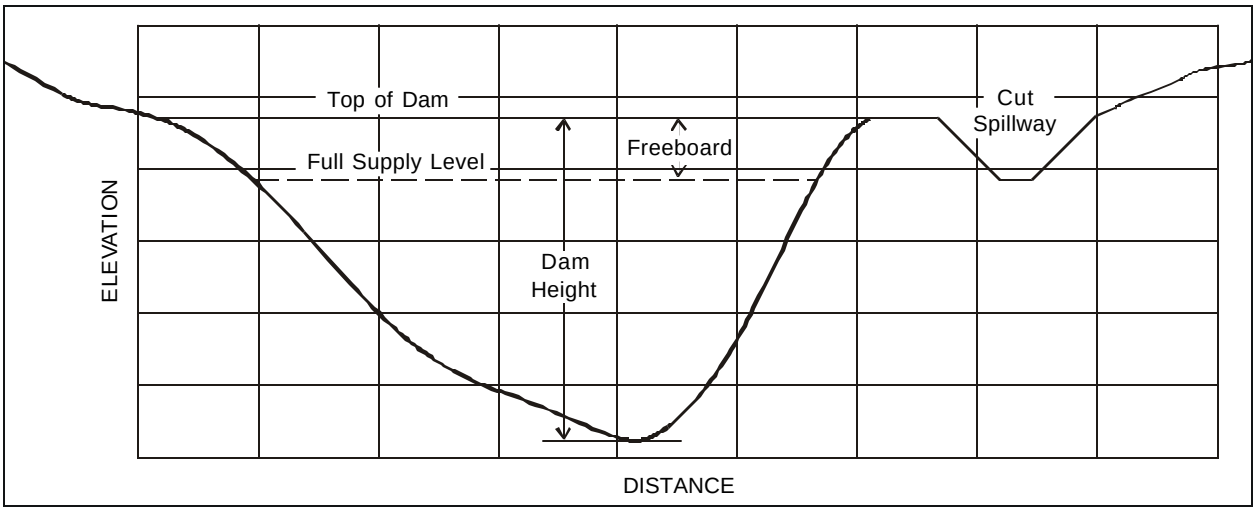
An overtopping failure as a result of storm runoff larger the spillway capacity.

Drawing No. 1 – Typical Plan, Profile and Section

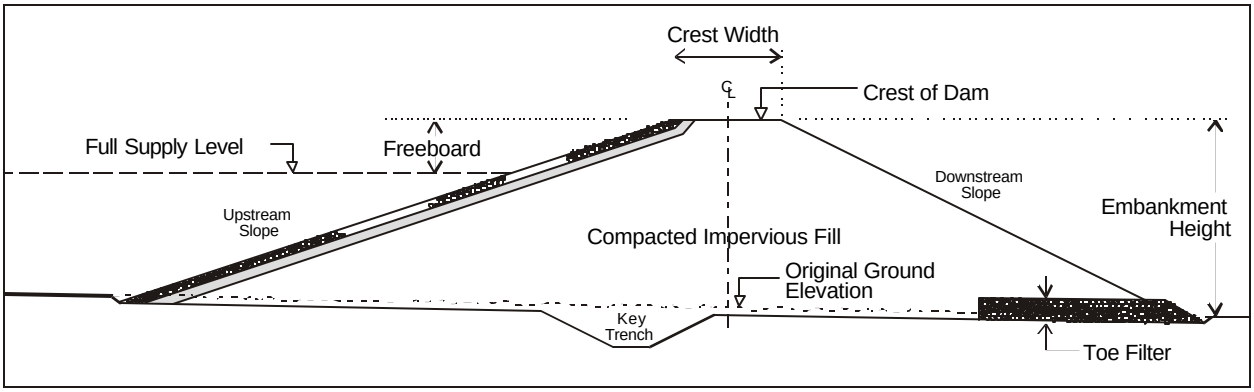
TYPICAL PLAN VIEW



TYPICAL CENTRE LINE PROFILE



TYPICAL DAM SECTION



4.0 The role of the Dam Safety and Water Projects Branch

On September 19, 1978, the Dam and Canal Safety Regulation was created by Order-in-Council. This regulation was created at the urging of the Association of Professional Engineers, Geologists and Geophysicists of Alberta, the former Department of Alberta Environment and other interested parties. This gave Alberta the first provincial Dam Safety Program in Canada.

All dams with a storage capacity of at least 30 dam^3 (24.3 acre-feet) and a height of at least 2.5 meters (8.2 feet) are covered by the current legislation. There are presently over 11,000 licensed dams in Alberta of which approximately 1,300 meet the above criteria. While there have been dam failures in Alberta, we are fortunate that no loss of life has occured.

The main purpose of the dam safety program is to ensure that structures are constructed, maintained and operated to acceptable standards. In 1998 the new Water Act and Regulations are scheduled to go into effect. The Dam Safety and Water Projects Branch of Alberta Environmental Protection administers the dam safety aspects of the Water Act, Regulations and Guidelines and periodically inspects all dams in Alberta which are covered by the Regulations. During these inspections any problems which may be present are noted and the owner is notified. It is then the responsibility of the owner to make any necessary repairs.

The Dam Safety and Water Projects Branch will provide general engineering advice to owners and referrals for specific problems (see General Information on page 23). Owners are strongly encouraged to inspect their projects on a regular basis and do any maintenance which may be required. Owners/operators having concerns or questions regarding their projects should contact the Dam Safety and Water Projects Branch at (403) 422-1355.

Table 1 – Inspection checklist

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

LOCATION	PROBLEMS	SUGGESTED INSPECTION
Upstream slope	Slope movement	After rapid drawdown of reservoir
	Displacement of slope protection	After severe wind storms, icing or heavy rain
	Tree and shrub growths	Year round
Crest	Settlement	After heavy rains
	Rutting	Autumn
	Tree and shrub growth	Year round
Downstream slope	Seepage	When reservoir is at F.S.L. or high
	Slope movement	After heavy rains
	Rodent burrows	Spring and fall
	Tree and shrub growth	Year round
Downstream toe	Seepage	During high reservoir levels
	Bulging – indicating a slide	After high reservoir levels or heavy rains
	Tree and shrub growth	Year round
Spillway	Debris blocking spillway or trash racks	Before spring runoff and periodically throughout the summer
	Erosion	After heavy rains or spillway operation
	Tree and shrub growth	Year round
Riparian outlet	Piping	During high reservoir levels and during operation of the outlet
	Corrosion or seam separation of conduit	Inspect annually (Corrugated steel conduits usually rust through in 25 to 30 years)

5.0 When should an inspection be done?

Small dams should be formally inspected at least once per year. The best time to look at a dam is in late spring or early summer, when the reservoir is at its Full Supply Level (FSL). Any seepage which might be occurring under, through, or around the dam will be most noticeable at this time. A couple of weeks of dry weather before the inspection is helpful in

determining whether wet areas below the dam are the result of seepage or rainfall. Under some conditions, seepage may be evaluated in mid winter when icing makes the active seep areas easy to see. The upstream slope, which is usually covered by water, should be inspected for erosion and burrowing animal activity when reservoir levels permit.

In addition to annual inspections, it is advisable to inspect projects after any severe weather events such as heavy rainfall, flooding, windstorms, severe icing, rapid snow melt, earthquakes, etc. These events can weaken or damage a dam.

6.0 What is required to do an inspection?

Only a few basic items are required to do a visual inspection:

- tape measure
- pen and paper or preferably an inspection form
- flashlight

A camera is very useful and highly recommended to record changes with time.
The "As Constructed" drawings for the project and any previous inspection notes and photos are very helpful.

7.0 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. Copies of the Inspection Report used by the Dam Safety and Water Projects Branch can be found at the end of this booklet. Use of this inspection format is encouraged and additional copies are available on request.

Before the field inspection, review notes from previous inspections, photographs and "As Constructed" drawings, if available. 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 slopes, the abutments, spillway channel(s), and the areas around the reservoir and below the dam. Any gates or control valves associated with the spillway, low level or riparian 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 conduits, pipes or access wells. Anything unusual or anything that has changed since the last inspection should be noted. For instance, any erosion, settlement, cracks, seepage or wet areas and their extent (often detected by a change in vegetation) or any other signs of deterioration should be noted and described.

Photographs should be taken during the inspection. Many of the problems which a dam may develop do not happen overnight 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. Section 12 on page 12 shows sketches of some of the common problems associated with dams. These sketches are intended to help identify the type of problem, its cause(s), concern(s) and recommended action(s).

8.0 General inspection guidelines

8.1 General problems

Dams can develop problems or fail for a number of reasons. Deficiencies in the design, poor construction practices and materials, inadequate spillway capacity or poor foundation conditions are the most common structural causes. Once a dam is constructed and operating, it can still develop problems or fail for reasons related to poor operation and maintenance, or conditions beyond the control of the owner/operator.

Failures can be classified into three general categories: erosion failures, piping failures and slope failures or slides. These failure categories are outlined by form, characteristics, causes and preventative measures on Tables 2, 3 & 4 on pages 5 and 6.

8.1.1 Erosion

The repair and prevention of erosion damage can be a chronic maintenance problem.
Erosion is not restricted to the main embankment but can occur on any component of the dam.
Erosion problems are easily identified by the loss or displacement of material.

If severe erosion damage is not dealt with, embankment or spillway failures can result. If the crest is reduced in width and height by erosion, the reduced freeboard then could allow flood waters to overtop the dam.

Table 2 Erosion failures

FORMS OF EROSION FAILURE	CHARACTERISTICS	CAUSES	PREVENTIVE MEASURES
Overtopping`	Flood water flows over embankment washing out the dam	Inadequate spillway capacity	Design the spillway with adequate capacity or provide an emergency spillway
		Clogging of spillway with debris	Install trash racks where possible or periodically remove debris
		Insufficient freeboard due to settlement or erosion of embankment	Regrade crest to design elevation
Wave Erosion	Upstream face eroded	Inadequate riprap or lack of bedding gravel, unprotected slope too steep	Place well-graded riprap and filters or flatten slope
Toe Erosion	Erosion of embankment toe near spillway or riparian outlet	Spillway or outlet located too close to dam	Discharge water away from the embankment. Provide protection
Surface Erosion	Surface runoff eroding downstream face of dam	Poor surface drainage and lack of adequate grass cover on the downstream slope	Provide drains or ensure adequate grass cover on the downstream face. Regrade crest towards upstream slope.

Table 3 – Piping failures

FORM OF PIPING FAILURE	CHARACTERISTICS	CAUSES	PREVENTIVE MEASURES
Piping	Progressive internal erosion of material usually starting from downstream side of dam or foundation and progressing upstream, eventually leading to a breach	Concentrated seepage	Install toe drains or filters
		Seepage along conduits	Grout along conduit to fill voids or replace conduit. Install filter at downstream end of conduit.
		Leaking conduit joints	Seal joints
		Rust perforation of conduits	Replace conduit

Table 4 – Slope failures/Slides

FORMS OF SLOPE FAILURE	CHARACTERISTICS	CAUSES	PREVENTIVE MEASURES
Foundation failure	Sliding of one or both slopes with heaving of the toe in direction of movement	Soft or weak foundation	Construct toe berms Flatten slope by adding material
		Excess water pressure in foundation	Provide drains and filters
Upstream slope failure	Slide in upstream slope	Slope too steep	Flatten slope Construct berm
		Rapid reservoir drawdown	Avoid rapid lowering of reservoir or flatten slope
Downstream slope failure	Slide in downstream slope	Slope too steep	Flatten slope Construct toe berm
		Saturation of slope by seepage	Provide proper drainage by installing filters

8.1.2 Seepage

Dams are not completely impervious. Some seepage can occur through, under or around them. Seepage can appear as a soft wet area, as standing water or, in some cases, as a flowing spring. It can emerge on the downstream slope, below the toe of the dam or on the downstream abutments. The presence of seepage can 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 they can lead to a slope failure. Concentrated seepage flows, if left uncontrolled, can cause progressive internal erosion of the dam resulting in a piping failure. Seepage is generally not a serious problem if adequate drains and filters are provided and if the seepage water is not allowed to pond at the downstream toe.

8.1.3 Instability

Instability can occur in the abutments, foundation and the embankment slopes. Factors which affect stability can include poor foundation conditions, poor construction practices, poor fill materials, overly steep slopes and uncontrolled seepage.

Instability 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 Section 12 - Identifying Problems and Solutions: A Self-Help Guide.

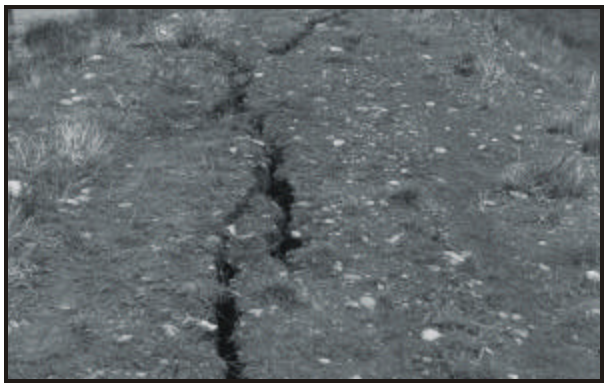


Photo No. 3 (DSB 9200-1)
Longitudinal cracking along crest of dam.

Photo No. 4 (DSB 9200-2)
Downstream slope failure (slump) following development of longitudinal cracking along crest.

8.2 The Crest

On most dams the crest is used as a crossing for vehicles and equipment and, in some cases, is well travelled by livestock. Ruts from 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.

During an inspection of the crest, look for the following problems:

-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.
-Cracks - longitudinal or transverse - which may indicate instability or differential settlement.
-Animal burrowing.
-Excessive vegetation.
-Sinkholes or any unexplained hole or cavity which might indicate internal erosion.

Photo No. 5 (DSB 9200-40)
Pedley Water Tank, 1976
Excessive vegetation on upstream slope.

Photo No. 6 (DSB 9200-39)
Pedley Water Tank, 1976
Excessive vegetation on downstream slope.

8.3 Upstream Slope

The upstream slope should be inspected for the following:

- Erosion from wave action.
- Displacement or loss of erosion protection.
- Cracks which can be an indication of slope instability or differential settlement.
- Sinkholes which are an indication of internal erosion and potential piping failure.
- Animal burrowing.

When the reservoir level is low more of the upstream slope is visible so it is a good time for an inspection.

Photo No. 7 (DSB 7823-24A)
Extensive erosion of the upstream slope caused by wave action. This has displaced all the riprap, created beaching and vertical scarps, reduced crest width and left the riparian outlet control unsupported.

8.4 Downstream Slope

The downstream slope should be inspected for the following:

- Cracks which can indicate slope instability or differential settlement.
- Seepage - 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 piping.
- 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 embankment if they die or blow over.
- Erosion caused by runoff.
- Rutting caused by livestock or vehicles.
- Animal burrowing.
- Standing or ponded water at the downstream toe which can cause slope instability.

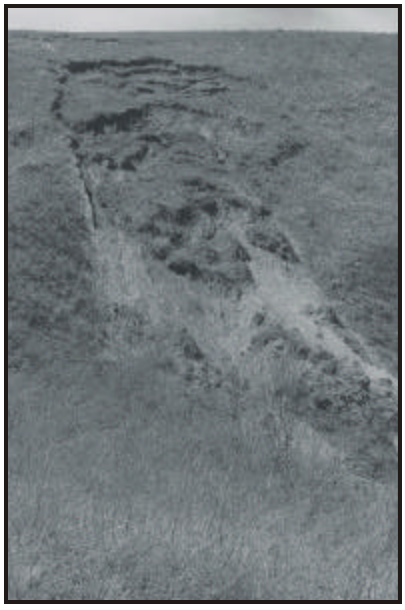


Photo No. 8 (DSB 18A-13)

A downstream slope failure (slide)

8.5 Downstream Abutments

Downstream abutments should be inspected for the following:

- Seepage, especially at the embankment/ abutment contact.
- Erosion of the embankment/abutment contact.
- Any other signs of abutment instability such as cracking or material displacement.

8.6 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.
- Flowing water with particle movement.

Seepage areas should be marked and their dimensions estimated for comparison during future inspections. Seepage flow should be estimated.

8.7 Riparian or Low Level Outlet

Riparian and low level outlets come in a range of designs, sizes, materials and types of control. 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 Section 12.7 on page 20). Corrugated steel conduits have a usual service life of 25 to 30 years before rusting through.

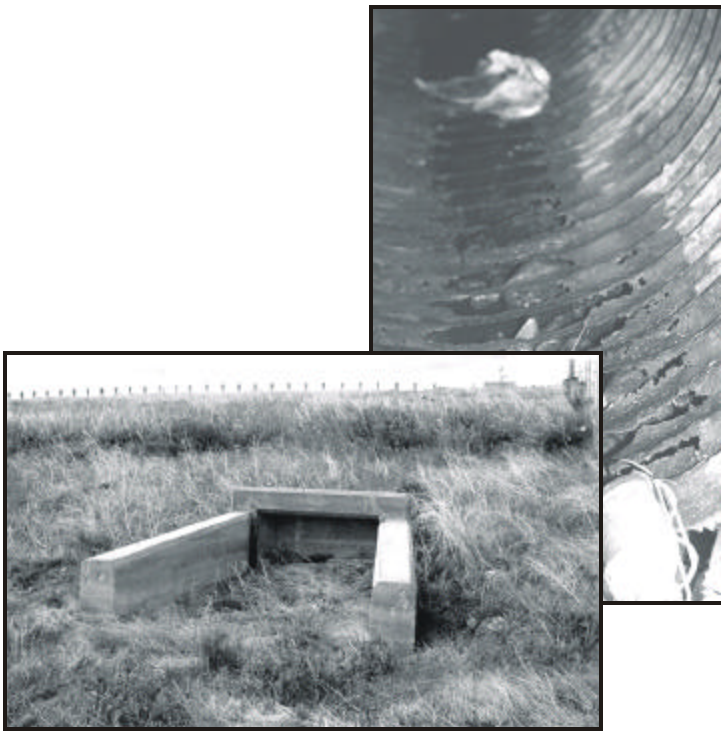
Outlet works should be inspected for the following problems:

- Damaged control valve or gate mechanism. (Because the control valve or gate is usually submerged, it cannot be physically inspected until reservoir levels permit. In this case, the only option is to test it).
- Silted inlet, a build-up of silt can usually be prevented by periodically operating the outlet.
- Deteriorated inlet and outlet structures.
- Dirty/murky or silty water flowing from the conduit or around it could indicate that internal erosion may be occurring.
- Low areas or sinkholes on the crest or downstream slope above the conduit may indicate internal erosion caused by piping along the conduit.
- Corrosion and perforations along the conduit.
- Joint separations along the conduit particularly if the conduit is constructed of corrugated steel pipe using seepage collars. If the conduit is 1.0 m or greater in diameter, an internal inspection is highly recommended.
- Erosion at the low level outlet.

Photo No. 9 (DSB 9200-41)
Slide gate control for a low level outlet damaged by ice action

Photo No. 12 (DSB 7763-09)
A low level outlet structure in very poor condition

Photo No. 11 (DSB 9209-24)
A low level inlet structure completely blocked by silt.



8.8 Spillways - General

A wide range of spillway types are in use and various materials are used in their construction.

Types: natural and cut channel, drop inlet, weir, chute and conduit.

Materials: concrete, timber, sheet pile, corrugated steel pipe, and natural or compacted soils.

Some spillways are unregulated while others are controlled by gates or stoplogs. The majority of small dams in Alberta have natural or cut channel spillways.

8.8.1 Natural or Cut Channel Spillway

The main problems to look for are:

- Erosion. This can occur anywhere along the length of the spillway channel, usually beginning where the slope is the steepest. The erosion usually gets deeper and progresses upstream each time the spillway operates.
- Displacement of erosion protection.
- Channel blockage by vegetation or debris. This can result in reduced spillway capacity and the possibility of the dam being overtopped by flood waters.

8.8.2 Corrugated Steel Pipe (C.S.P.) Spillway

The main problems to look for are:

- Joint or seam separation.
- Corrosion and perforations which can cause internal erosion and piping.
- Erosion of the spillway outlet.

Photo No. 12 (DSB 8644-6)
A badly corroded conduit in a low level outlet. Note the erosion occurring under the conduit. This erosion has created a large cavity around the conduit extending upwards through the embankment to the crest.

8.8.3 Concrete Spillways

The main problems to look for are:

- Cracks which expose the reinforcing steel and allow water entry.
- Spalling (caused by freeze/thaw or chemical action) which exposes the reinforcing steel.
- Joint separations or misalignment.
- Drains or weep holes which are plugged.
- Erosion of the spillway foundation leaving the concrete unsupported.

Photo No. 13 (DSB 7745-11)
A hole which developed through an embankment as a result of a piping failure.

9.0 Maintenance

One of the responsibilities of owning and operating a dam, regardless of its size, is a commitment to maintaining 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 condition 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 could eventually result.

10.0 Emergency planning

If the failure of a dam could cause a hazard to life and property, the dam owner is required to 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 immediately – name, location, phone number.
- What can be done at the damsite to manage the situation, what equipment is needed?
- Who else should be notified? (i.e., police, local government, road authorities, etc.)

This plan should be distributed to emergency stakeholders and updated periodically.

The Dam Safety and Water Projects Branch, Alberta Environmental Protection can provide guidance on emergency plans.

11.0 Record keeping

It is recommended that all records relating to the dam such as the water rights licence, "As Constructed" plans, inspection records, photographs, emergency plans, correspondence, etc. should be kept together. This will provide a history of the dam for future use.

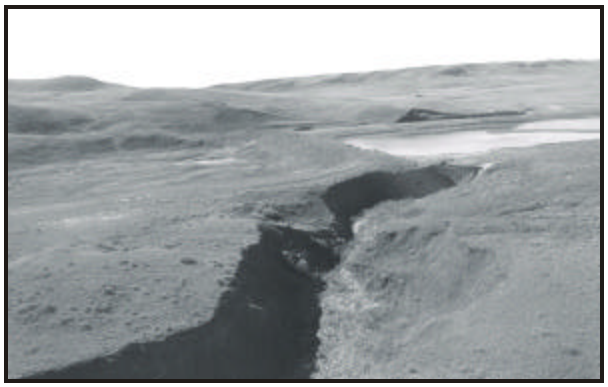


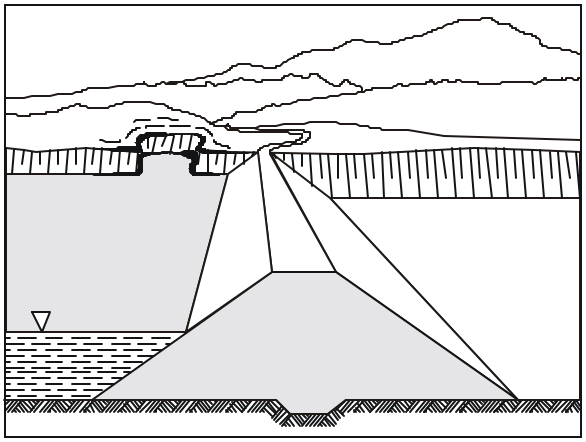
Photo No. 14 (DSB E7824-21)
A badly eroded spillway channel. As the erosion progresses upstream, the threat of the reservoir draining through this channel increases.

Photo No. 15 (DSB 8402-1)
A timber chute spillway in very poor condition.

Identifying problems and solutions: a self-help guide

12.1 Reservoir Problems

SLIDES AND SLOUGHS

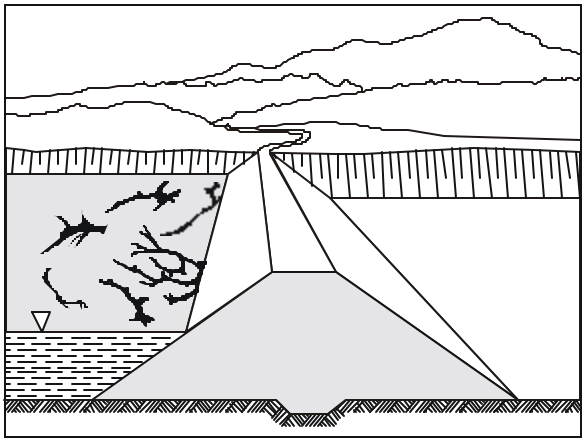


Causes:
1. Ice action and wave erosion creates steep slopes.
2. Toe of the slope becomes saturated by the reservoir.

Concerns:
1. The slide or slough could block the spillway or outlet.
2. Waves caused by a slide may overtop the embankment.

Recommended action:
1. Monitor the area and contact an engineer if the embankment is threatened.

FLOATING DEBRIS

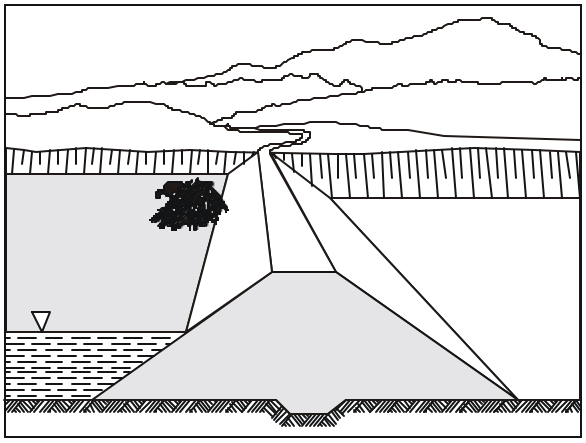


Causes:
1. Beaver activity in the drainage basin.
2. Tree cutting.
3. Heavy runoff.

Concerns:
1. Debris may block spillway or outlet.

Recommended action:
1. Install trash racks where necessary and clean them as required.

BEAVER ACTIVITY



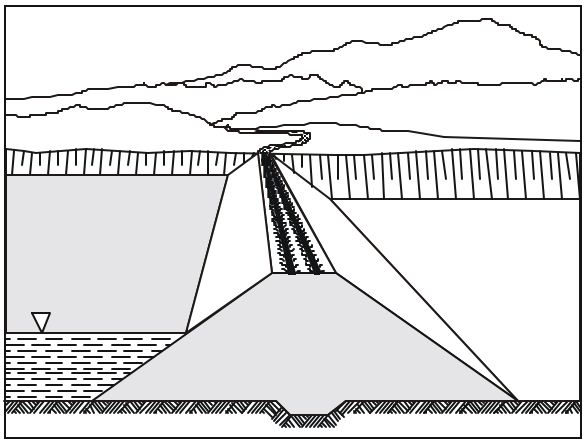
Causes:
1. Beaver activity around the dam.

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

Recommended action:
1. Contact the local municipality to have the beavers removed.

12.2 Crest Problems

RUTS ALONG CREST

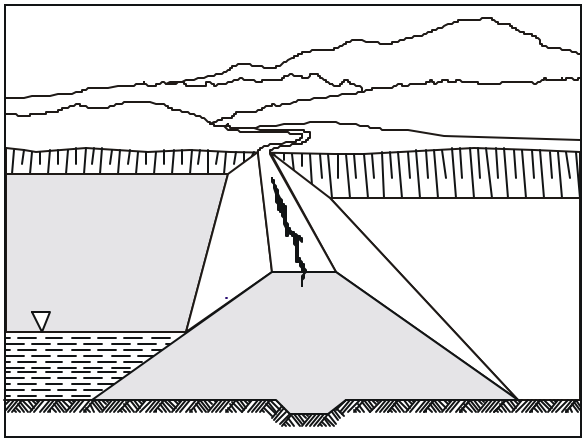


Causes:
1. The main cause is inadequate drainage of the crest allowing water to stand.
2. Vehicle crossing when surface is soft or wet.

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

Recommended action:
1. Re-grade and re-compact crest to original elevation with a slope toward the upstream slope.
2. Provide surface resistance to rutting by adding gravel.

LONGITUDINAL CRACKS

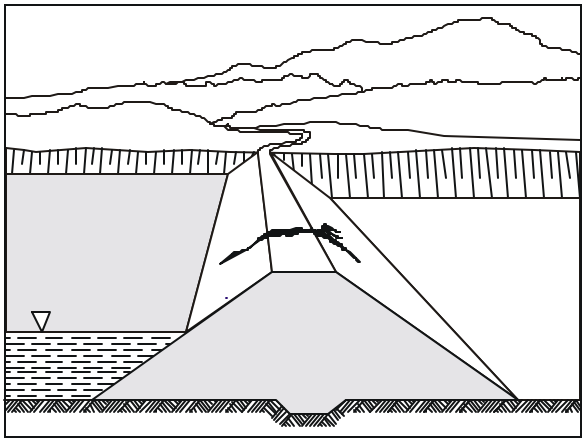


Causes:
1. Uneven settlement within the embankment or foundation.
2. Slope instability.

Concerns:
1. Provides an entry point for surface water which can promote movement.
2. Can reduce the effective crest width.

Recommended action:
1. An engineer should determine the cause of the crack and recommend a course of action.
2. The crack(s) should be excavated and backfilled with compacted material to prevent seepage.
3. Area should be closely monitored for future movement.

TRANSVERSE CRACKING

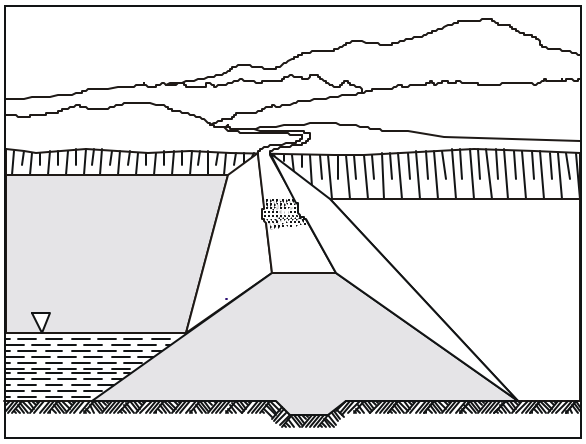


Causes:
1. Uneven movement between two adjacent segments of the embankment.
2. Instability of the embankment or foundation.

Concerns:
1. Provides an entry point for surface water.
2. May create a seepage path from the reservoir and a potential piping failure.

Recommended action:
1. An engineer should determine the cause of the crack and recommend a course of action.
2. The crack(s) should be excavated and backfilled with compacted material to prevent seepage.
3. Area should be closely monitored for future movement.

LOW AREA ON THE CREST

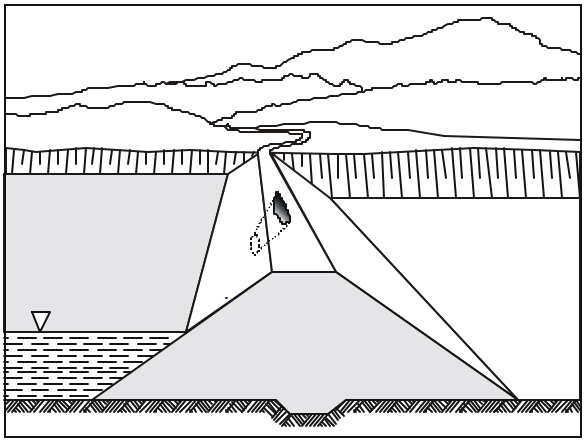


Causes:
1. Excessive settlement of the embankment material or the foundation (area of deepest fill usually settles the most).
2. Internal erosion of the embankment material.
3. Prolonged erosion from wind or water
4. Poor construction practices.

Concerns:
1. Reduces freeboard for safe routing of flood waters.
2. Concentrates flow at one area if the dam is overtopped.

Recommended action:
1. An engineer should determine the cause of the low area and recommend method to repair and prevent reoccurrence.
2. Re-grade the crest to original design elevation.

SINKHOLE ON THE CREST



Cause:
1. Internal erosion from seepage, for example, piping into a hole in the conduit.
2. A breakdown of dispersive clays by seepage (this is a concern in some areas of Southern Alberta).

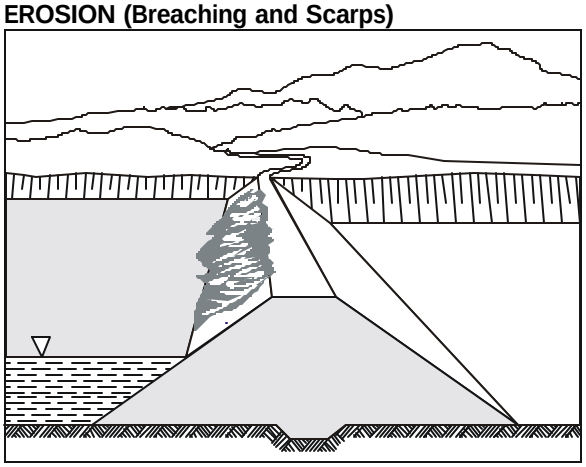
Concerns:
1. Sloughing / caving can occur in the sinkhole leading to embankment instability and development of a low area.
2. Provides an entrance point for surface water.
3. Depending on size and depth, may lead to a failure.

Recommended action:

An engineer should determine the cause of the sinkhole and recommend a method of repair.

12.3 Upstream Slope Problems

EROSION (Breaching and Scarps)



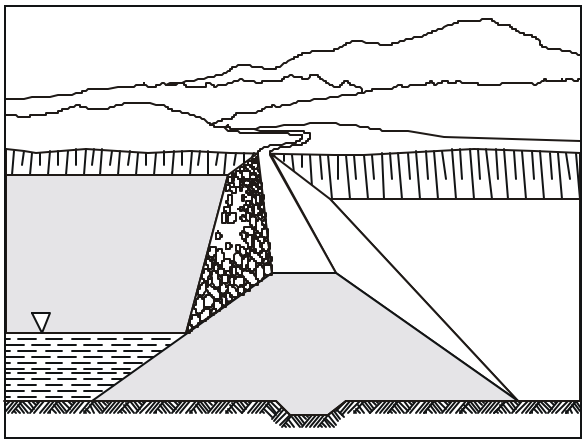
Causes:
1. Wave or ice action.
2. Local settlement.
3. Inadequate erosion protection.

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

Recommended action:
1. Re-grade the upstream slope to the original design grade.
2. Provide adequate slope protection or flatten slope by adding material.

12.3 Upstream Slope Problems *(cont.)*

DISPLACED OR WEATHERED RIPRAP

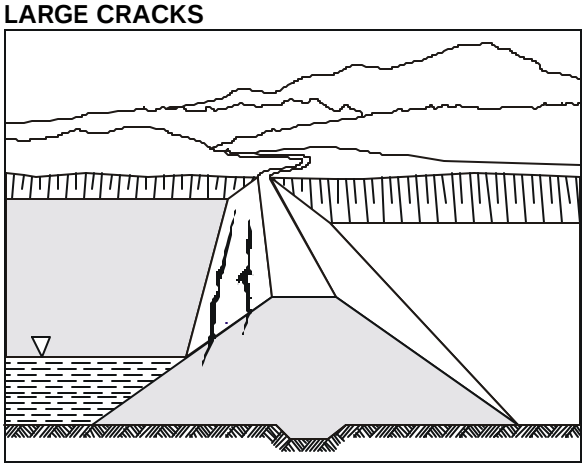


Causes:
1. Wave or ice action.
2. Poor quality riprap.
3. Same size rock, leaving gaps which allow waves to erode underlying material.

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

Recommended action:
1. Repair erosion damage.
2. Re-establish adequate slope protection with underlying filter bed.

LARGE CRACKS

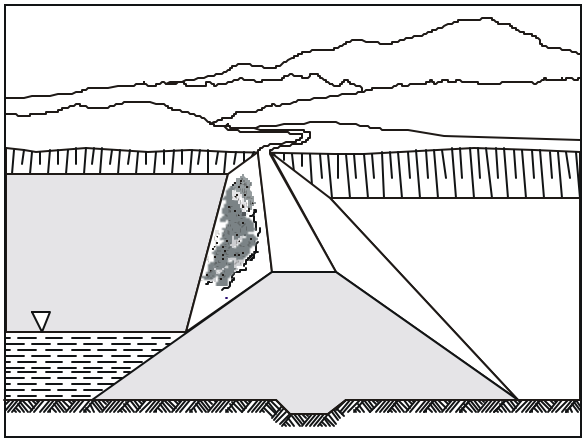


Causes:
1. Slope instability.
2. Differential settlement.

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

Recommended action:
1. The reservoir should be drawn down.
2. The engineer should determine the cause and recommend a course of action.

SLIDE OR SLUMP



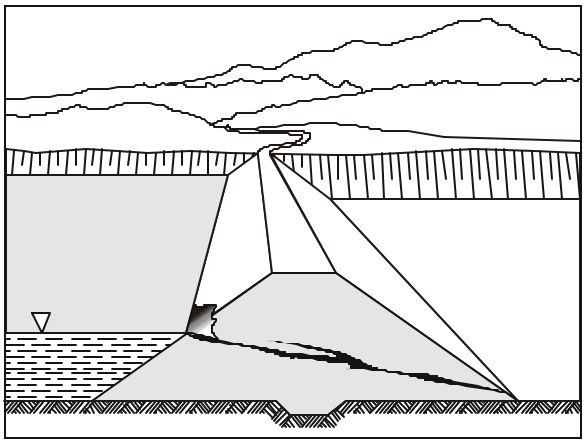
Causes:
1. A foundation failure.
2. Too steep a slope.
3. A rapid draw down of the reservoir.

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. Should advise affected downstream owners who would be affected by releases.
2. The engineer should determine the cause and recommend a course of action.

12.3 Upstream Slope Problems *(cont.)*

SINKHOLE



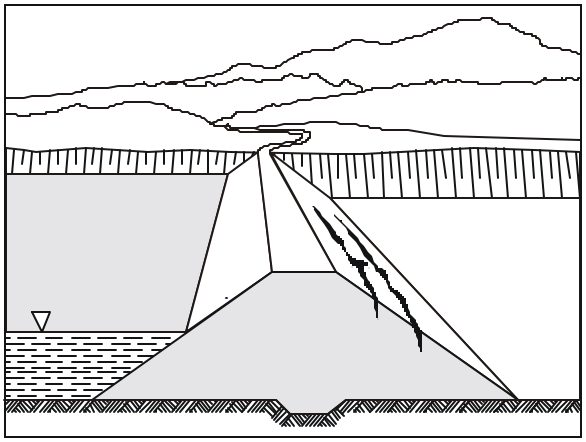
Causes:
1. Concentrated seepage begins to erode embankment material through the dam. This loss of material causes the inlet of the "pipe" to collapse forming a sinkhole.

Concerns:
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.
2. An engineer should evaluate the situation and recommend a course of action.

12.4 Downstream Slope Problems

LONGITUDINAL CRACKING

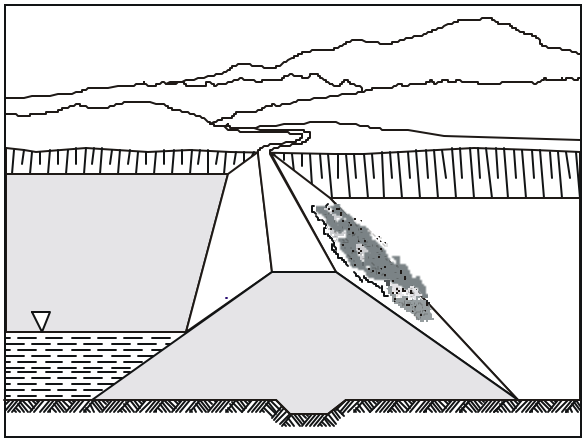


Causes:
1. Drying and shrinking of embankment material.
2. Settlement of embankment or foundation material.
3. Slope instability.

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

Recommended action:
1. Drying cracks should be sealed.
2. An engineer should determine the cause of the cracks and recommend a course of action.

SLUMP/SLIDE



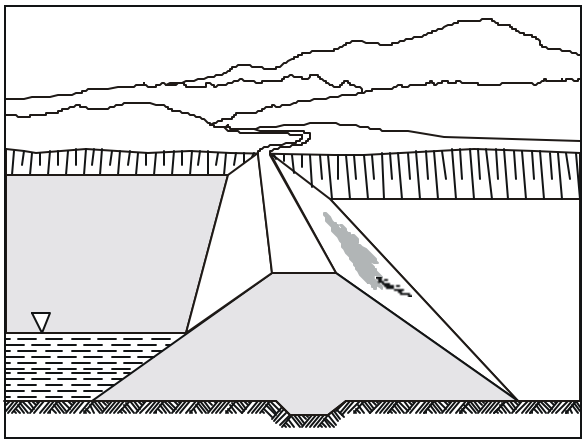
Causes:
1. Too steep a slope.
2. Loss of embankment material strength from excessive seepage.

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

Recommended action:
1. Draw down the reservoir.
2. An engineer should determine the cause and recommend a course of action.

12.4 Downstream Slope Problems *(cont).*

WET AREAS/SEEPAGE

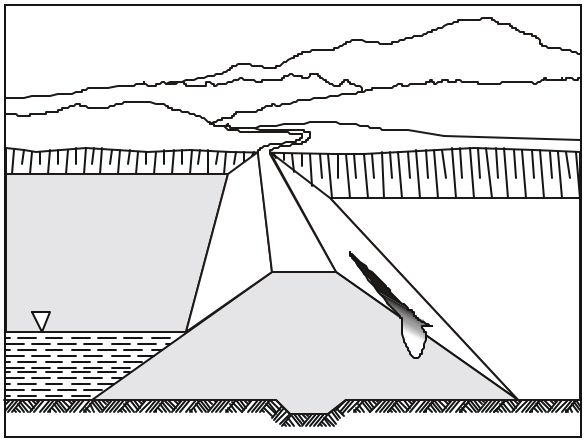


Causes:
1. Seepage through the embankment or under the foundation.
2. Surface water entering through cracks or animal burrows.

Concerns:
1. Creates slope instability which can lead to a failure.
2. Indicates the possibility of a piping failure.

Recommended action:
1. The outflow should be examined for dirty water - an indication that piping may be occurring.
2. The area and flow should be monitored and the reservoir drawn down if flows increase.
3. An engineer should assess the situation and recommend a course of action.
4. Consult an Engineer immediately if flow volume increases or dirty water is present.

CAVE IN/COLLAPSE

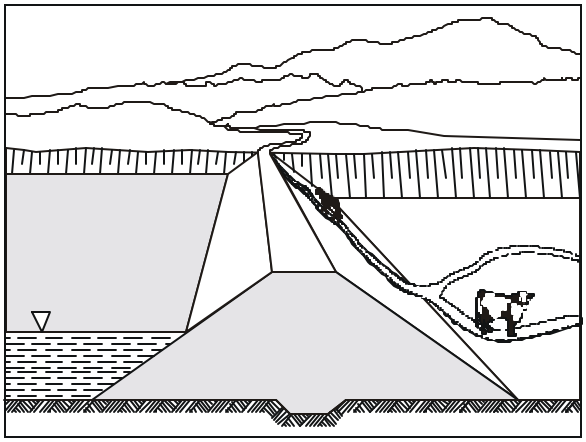


Causes:
1. Poor compaction during construction.
2. Internal erosion / piping through the embankment or foundation.
3. Animal burrowing.

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

Recommended action:
1. Monitor the area for change.
2. An engineer should determine the cause and recommend a course of action.

EROSION



Causes:
1. Livestock traffic.
2. Surface runoff.

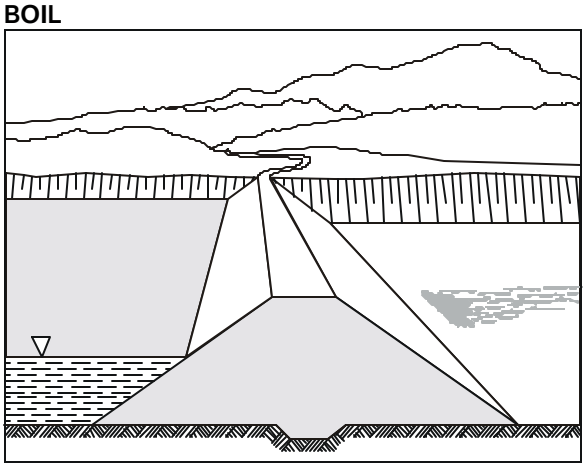
Concerns:

Encourages further erosion.

Recommended action:
1. Re-grade slope and sow a cover crop.
2. Keep livestock away from the embankment.

12.5 Downstream Toe Problems

SEEPAGE WATER EXITING FROM A WATER BOIL

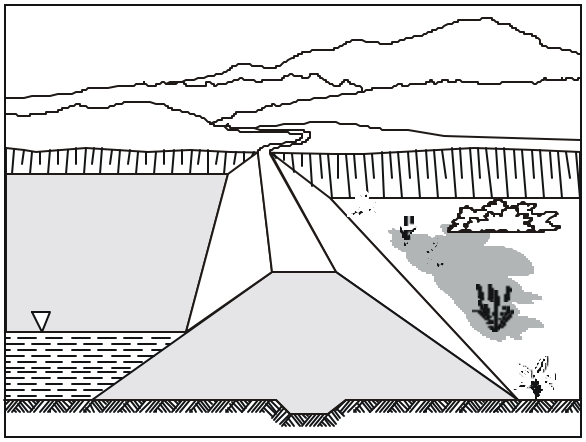


Causes:
1. A concentrated seepage path or "pipe" has developed through the foundation.
2. Seepage from the reservoir through a sand or gravel layer in the foundation.

Concerns:
1. May result if a piping failure of the foundation and ultimately the embankment.

Recommended action:
1. The outflow should be examined for dirty water - an indication that piping may be occurring.
2. The area and flow should be monitored and the reservoir drawn down if flows increase.
3. An engineer should assess the situation and recommend a course of action.
4. Consult an Engineer immediately if flow volume increases or dirty water is present.

STANDING/PONDED WATER AT THE DOWNSTREAM TOE



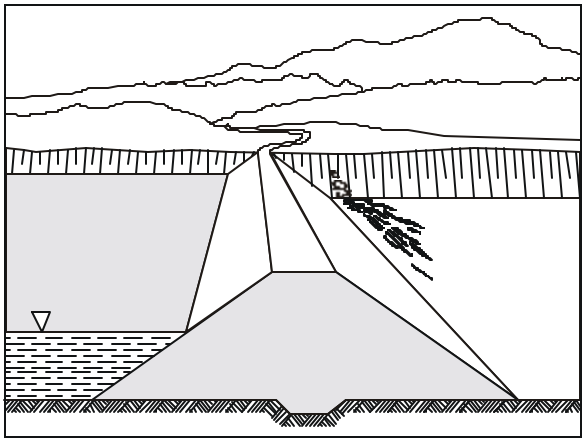
Causes:
1. Heavy seepage.
2. Surface runoff.
3. Poor drainage away from the toe, for example, due to beaver dams.

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

Recommended action:
1. Provide adequate drainage to prevent ponding.
2. Identify seepage path and consult an engineer if necessary.
3. Consult an Engineer immediately if flow volume increases or dirty water is present.

12.6 Downstream Abutment Problems

WET AREAS OR WATER EXITING FROM DOWNSTREAM ABUTMENT



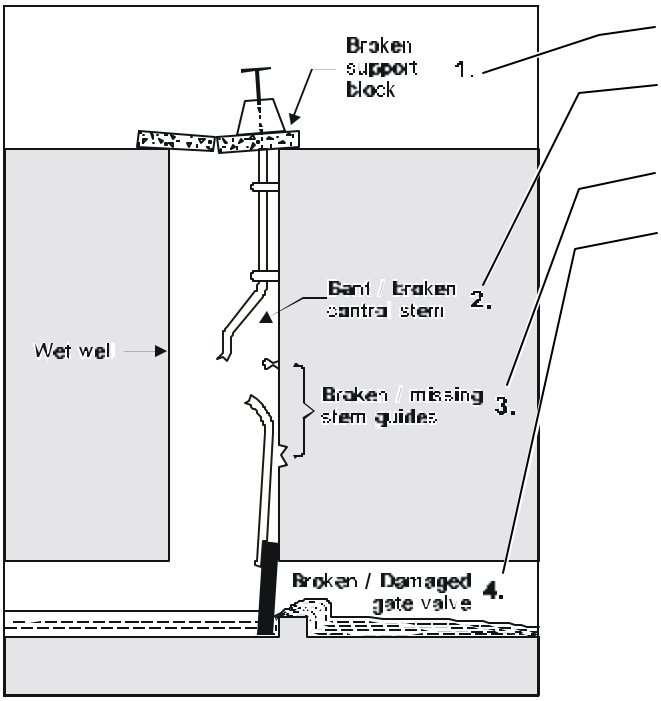
Causes:
1. A seepage path or "pipe" passing around the embankment through the natural abutment material.

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

Recommended action:
1. The outflow should be examined for dirty water - an indication that piping may be occurring.
2. The area and flow should be monitored and the reservoir drawn down if flows increase.
3. An engineer should assess the situation and recommend a course of action.
4. Consult an Engineer immediately if flow increases or dirty water is present.

12.7 Riparian or Low Level Outlet Problems

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 force 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 waterborne debris.

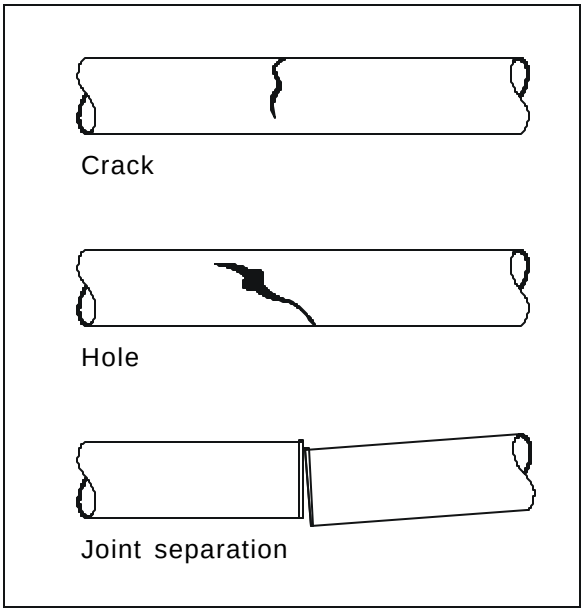
Concerns:

1. Gate becomes inoperable preventing a draw down of the reservoir, if required, and preventing passage of riparian water to downstream users.
2. If gate is jammed open then reservoir operating levels cannot be maintained and water is lost.

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.

CONDUIT IN POOR CONDITION



Causes:

1. Rust.
2. Joint separation.

Concerns:

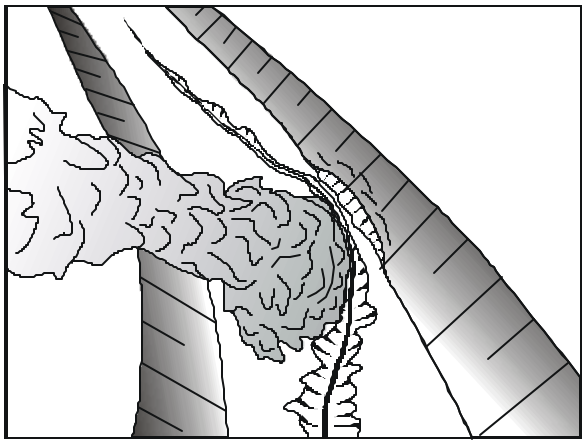
1. May lead to serious internal erosion and a possible piping failure

Recommended action:

1. An engineer should determine the cause and recommend a course of action.

12.8 Spillway Problems

ERODED CHANNEL/SLIDE

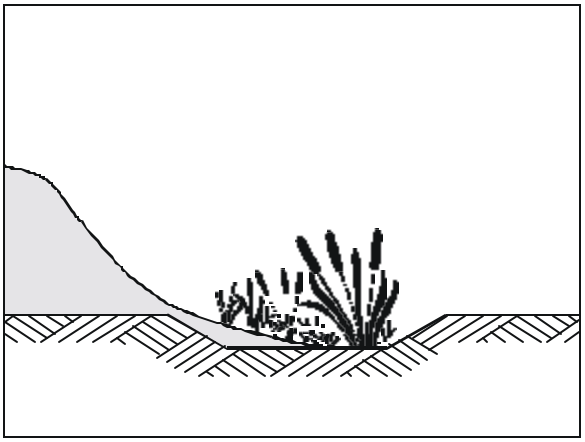


Causes:
1. Inadequate erosion protection.
2. Too steep a gradient.

Concerns:
1. Erosion channel deepens and generally works its way upstream.
2. Can result in the reservoir draining through the eroded channel.
3. Slides can block the channel.

Recommended action:
1. Repair the eroded area with compacted fill.
2. Provide adequate erosion protection.
3. Re-grade the channel if necessary.

BLOCKED CHANNEL



Causes:
1. Floating debris.
2. Animal activity.
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.

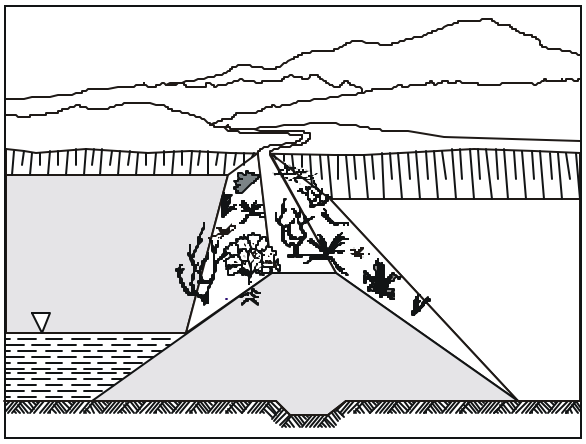
OTHER PROBLEMS

Causes:
1. 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. Regularly inspect and maintain the spillway.
2. If uncertain about a particular problem, an engineer should be consulted.

12.9 Miscellaneous Problems

EXCESSIVE VEGETATION

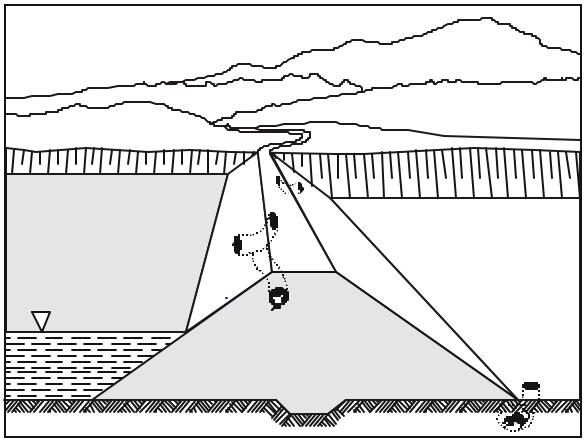


Causes:
1. Lack of maintenance.

Concerns:
1. Prevents a thorough inspection.
2. If vegetation dies the root system could create a seepage path.
3. If trees blow over the root ball could leave a hole.
4. Prevents easy access.
5. Provides a habitat for burrowing animals.

Recommended action:
1. Remove excessive vegetation and root systems.

BURROWING ANIMAL ACTIVITY



Cause:
1. Burrowing animals.

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

Recommended action:
1. Control rodents.
2. Remove favorable habitat conditions.
3. Backfill rodent burrows with compacted fill or grout.

13.0 General information and addresses

Licensees or other persons should contact the Dam Safety and Water Projects Branch if they require further information on any of the following:

- Inspections,
- Problems concerning the operation, maintenance or safety of their dam(s),
- Legislation on dam safety; and,
- Any other questions or concerns relating to their project(s),

The address is:

Dam Safety and Water Projects Branch
Alberta Environmental Protection
8th Floor, Oxbridge Place
Edmonton, Alberta T5K 2J6
Phone: (403) 422-1355
Fax: (403) 427-6334

Long distance callers within Alberta can contact their nearest R.I.T.E. operator or dial 310-0000 for toll free service.

Referrals

The Dam Safety and Water Projects Branch will give general engineering advice but for specific problems may refer the caller to one of the following:

a) Prairie Farm Rehabilitation Administration (P.R.F.A.)
Agriculture Canada
632, 220 - 4th Avenue S.E.
Calgary, Alberta, T2G 4X3
Phone: (403) 292-5638
P.F.R.A. may be able to provide advice on design, construction, operation and maintenance to groups, communities, farmers and ranchers in the prairie provinces. Financial assistance may be available through one of its funding programs.

b) Consulting Engineers of Alberta
Suite 505, 22 Sir Winston Churchill Ave, St. Albert, Alberta T8N 1B4
Phone: (403) 458-1852
For names of consulting engineers

c) Ducks Unlimited Canada
202, 10470 - 176 Street
Edmonton, Alberta T5S 1L3
Phone: 489-2002 or FAX 489-1856

If the project is situated in certain Parkland or Prairie agricultural zones, Ducks Unlimited Canada may assume conditional responsibility for the project's operation and maintenance.

Other publications by the Dam Safety and Water Projects Branch include the following:

D.S.B.3 Dam and Canal Safety Guidelines
This booklet explains the working of the Regulation as it is administered by the Dam Safety and Water Projects Branch.

D.S.B.4 Inventory of Dams
The Inventory lists all dams in Alberta which are governed by the terms of the Regulation.

D.S.B.6A Dam Owners' Guidelines for the Preparation of Emergency Preparedness Plans
This booklet details the requirements for preparing Inundation Studies and Emergency Preparedness Plans.

14.0 Glossary

*A*butment

The undisturbed natural material below the excavation surface and immediate surrounding formation above the normal river level or flood plain against which the ends of the dam are placed. Left and right abutments are those on respective sides of an observer when looking downstream from the top of the embankment.

Axis of Dam

The vertical plane or curved surface of reference between abutments around which the dam is designed and located. The location of this plane of reference may differ among dam designers.

*B*ase of Dam

The general foundation area of the lowest portion of the main body of the dam, i.e. the portion excluding the abutments.

Berm

A horizontal step or bench in the sloping profile of an embankment dam.

Breach

A break, gap or opening (failure) in a dam which releases reservoir water.

*C*onduit

A closed channel for conveying discharge through or under a dam. May be constructed of corrugated steel pipe, concrete or plastic pipe.

Core

A zone of soil of low permeability in an embankment dam.

Crest Length

The total horizontal distance measured along the axis at the elevation of the top of the dam between the ends of dam.

Crest of Dam

Frequently intended to denote top of dam. See "Top of Dam."

Cut-off Trench

A trench excavated below the general level of the base of the dam to connect the impervious membrane or zone to a suitably impervious stratum in the foundation.

*D*am

A barrier constructed for storage, control, or diversion purposes. A dam may be constructed across a natural watercourse or on the periphery of a reservoir. Natural barriers formed by ice, landslides, or earthquakes are excluded.

Dispersive Clay

A type of clay which, because of its chemical and physical properties, tends to break down or dissolve easily in the presence of water.

Drain

A layer of pervious material or a pipe to facilitate drainage.

Drainage Area

The area drained by the stream or watercourse down to the point at which the dam is located.

Drawdown

The lowering of water surface level due to release of water from the reservoir.

Dyke

A long low embankment dam. Also a levee. The term Dyke is usually applied to auxiliary dams used to close off areas that would otherwise be flooded by the reservoir.

*E*mbankment Dam

Any dam constructed of natural excavated materials placed without addition of binding materials.

Emergency Preparedness Plan

A predetermined plan of action to be taken to reduce the potential for property damage and loss of lives.

Engineer

A registered professional engineer in Alberta with experience and expertise in the design and inspection of dams.

*F*ailure

An incident resulting in the uncontrolled release of water from a reservoir.

Filter Zone

A section of an embankment comprising a zone of granular material to prevent migration of material from one zone to another. Sometimes the filter zones are also designed to act as drains.

Flashboards

Sections of timber, concrete and/or steel fitted to the overflow crest of a spillway in such a way that they can be removed. Flashboards may be put in place to increase storage capacity and are removed or collapse automatically when water level exceeds a predetermined level. Flashboards are usually designed for temporary and infrequent use.

Floodplain

An area adjoining a body of water or natural stream that has been or may be covered by flood water.

Foundation of a Dam

The undisturbed natural material below the excavation surface on which the dam structure is placed. The term Foundation includes any treatment such as piling, grout caps, and curtains and cut-off walls below the general base of the dam, but would not include cut-off trenches.

Freeboard

The vertical distance between the top of the dam and the water level for the condition for which the freeboard is stated, such as: "freeboard above maximum water surface" or "freeboard above normal reservoir level".

Full Supply Level

The maximum storage retention level when the reservoir is full, usually corresponding to the level of the spillway crest for an ungated spillway or to the water level for which the dam is designed.

*G*ate

A general term for any mechanical device to control the flow of water in intakes, outlet works and on spillway crests. The term Gate generally applies to leaf or drum type segments which are operated by raising and lowering as opposed to valves in closed circular conduits.

*H*eight of Dam

Difference in elevation between the crest elevation and the lowest point at the downstream toe.

*I*ntake

Any structure on the upstream dam face or within the reservoir for the purpose of directing water into a confined conduit, tunnel, canal, or pipeline.

Internal Erosion

See Piping.

*L*ow Level Outlet (Bottom Outlet)

An opening at a low level from a reservoir generally used for emptying the reservoir or for scouring sediment. See Riparian Outlet.

*M*aintenance

The upkeep necessary for efficient operation of dams and their appurtenant works not to be confused with alterations or repairs.

Maximum Section of Dam

A cross-section of the dam perpendicular to its axis at the greatest height of the dam.

*O*wner

Any person or legal entity, who owns, leases, controls, operates, maintains or manages a dam or reservoir.

Outlet

A discharge opening lower than the spillway crest designed to release reservoir water through or around the dam

Outlet Gate

Any gate designed to control the flow of water through a reservoir outlet in or around the dam.

*P*iping

The progressive development of internal erosion by seepage, appearing downstream as a hole or seam discharging water that contains soil particles.

Probable Maximum Flood (PMF)

An estimate of the flood that would result from the most severe combination of critical meteorologic and hydrologic conditions possible in the region.

*R*eservoir

An artificial lake, pond or basin for the storage, regulation and control of water, and other liquid or liquid-carried material or sediment.

Reservoir Area

The surface area of the reservoir measured in a horizontal plane at an elevation corresponding to the full supply level of the reservoir. The area that would be flooded due to backwater elevations or surcharge is not included.

Reservoir Capacity

The total volume which the reservoir is capable of holding when filled to the full supply or normal water level. Storage derived from temporary flashboards, surcharge or blackwater curve is not included. Reservoir capacity usually is reported as of the date of construction of the dam.

Riparian Outlet

An outlet structure designed to pass water through the dam for the benefit of downstream water users.

Riprap

A layer of stone, precast blocks, bags of concrete or suitable other material, generally placed on the upstream slopes of an embankment or along a watercourse as protection against wave action, erosion or scour. Riprap is usually placed by dumping or other mechanical methods and in some cases is hand placed. It consists of pieces of relatively large compared to a gravel blanket.
See Slope Protection.

*S*eepage

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

Seepage Collar

A projecting collar, usually steel or concrete, built around the outside of a pipe, tunnel or conduit under an embankment dam, to lengthen the seepage path along the outer surface of the conduit.

Slope

The inclined face of a canal or embankment or the grade of the spillway floor.

Slope Protection

Protection of embankment slopes against wave action, erosion or scour. It may take various forms, such as riprap, concrete slabs, cement stabilized soil, asphaltic concrete, gravel or vegetation.

Slump

A portion of earth embankment which moves downslope, sometimes suddenly, often with cracks developing at the upper end and a noticable bulge at the toe of the slump.

Spillway

A chute, weir, conduit, tunnel, channel or other structure designed to permit discharges from the reservoir. The spillway is principally to discharge floodflows safely past a dam but may be used to release water for other purposes. A spillway may be gated (controlled) where gates are used to regulate the level of the reservoir above the spillway crest. In an ungated (uncontrolled) spillway the discharge occurs automatically when the water level rises above the level of the spillway crest.

Emergency Spillway - A secondary spillway designed to operate only during large floods. The Emergency spillway crest is higher than the service spillway crest.

Service Spillway - The main spillway for normal and flood flows.

Spillway Capacity

The flow which the spillway is capable of discharging when the reservoir is at its maximum designed water surface elevation.

Spillway Crest

The uppermost portion of the overflow section.

Spillway Gate

Any mechanical device designed to control the flow of water through or over a spillway.

Stilling Basin

A pond, basin or reservoir, riprapped or in a natural state, formed downstream of the main dam, usually by means of a sill, small auxiliary dam or weir, to protect the streambed from scour caused by spillway and outlet discharges. The basin serves as an energy dissipator.

Stop Logs

Logs, timbers, concrete or steel beams stacked vertically on each other in guides or slots so as to close off entrance to dam outlets or penstocks. Normally stoplogs are used to temporarily block an outlet to provide access for repair or inspection of permanent facilities.

*T*oe of Dam

The junction of the downstream face of the dam with the base or foundation surface.

Top of Dam

The elevation of the uppermost surface, usually the roadway or walkway or the non-overflow section of the dam.

Top Width

The horizontal distance from upstream to downstream face measured perpendicular to the axis at the top of the dam.

Trashrack

A screen or grill placed at the inlet end of spillways and outlets to prevent the entrance of logs, timbers, trash, or other debris in the reservoir.

*W*eir

An overflow structure frequently used for measuring discharge. However, in dam terminology it is also the crest of a spillway controlling the upstream surface level. Also a structure whose prime purposes is to raise the water level to divert a water course.

Project _____ File # _____

Location _____ NTS _____

Inspector _____ Date _____

Project Code _____ Next Inspection _____

Latitude _____ Longitude _____

DAM SAFETY AND WATER PROJECTS BRANCH

1. EMBANKMENT

Dam Height: _____ Capacity: _____ Top Width: _____

Material: _____ Crest Length: _____

U/S Slope: _____ Vegetation: _____ Condition: _____

Comments: _____

U/S Protection: _____ Size: _____

Condition: _____

Comments: _____

D/S Slope: _____ Vegetation: _____ Condition: _____

Seepage: _____

Comments: _____

2. OUTLETS

(a) Conduit

Location: _____ Condition: _____

Type: _____ Size: _____

Inlet: _____

Outlet: _____

Barrel: _____

Well/Gate: _____

D/S Protection: _____

Comments: _____

(b) Spillway

Location: _____ Condition: _____

Type: _____ Capacity: _____

Inlet Channel: _____

Bed Width: _____ Weir: _____ Diameter: _____

Floor Slab: _____

Chute/Wing Walls: _____

Outlet Channel: _____ Side Slope: _____

Drains: _____

D/S Protection: _____

Comments: _____

(c) Emergency Spillway

Location: _____ Condition: _____

Type: _____ Bed Width: _____

Comments: _____

3. ABUTMENTS

Erosion: _____ Condition: _____

Seepage: _____

Comments: _____

4. RESERVOIR

Use: _____ Level: _____

Source of Supply: _____ Drainage Area: _____

Condition: _____

5. CONDITION D/S OF DAM

Channel Dimension: _____

Vegetation: _____

Habitation: _____

Structures: _____

Tributary to: _____

Comments: _____

6. REPAIRS RECOMMENDED:

_____

7. PHOTOGRAPHS: _____

8. LICENSEE: _____

Address: _____ Phone: _____

9. DOES PROJECT COMPLY WITH PLANS? _____

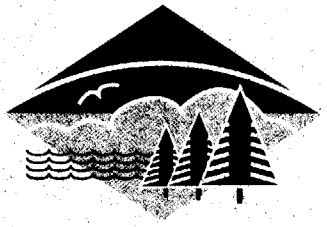
_____

11. SKETCHES AND ADDITIONAL COMMENTS: _____

Related Web Sites

1. Alberta Environmental Protection http://gov.ab.ca/env/water/reports.html
2. P.F.R.A http://www.agr.ca/pfintroe.htm
3. Ducks Unlimited http://vm.ducks.ca/index.html
4. Consulting Engineers of Alberta http://www.cea.caisnet.com

Alberta
ENVIRONMENTAL PROTECTION
Natural Resources Service
Water management Division
Dam Safety and Water Projects Branch



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