Appendix 5
Checklist of Advice Concerning Dam Safety Inspections and the Preparation of Reports

This detailed advice applies to periodic and special inspections for physical integrity in the dam and to comprehensive inspections which assess the overall safety management of the dam. This checklist:

- defines the information about the structure that needs to be gathered during the inspection
- gives examples of the defects and problems that may be encountered
- requires the formulation of recommendations on remediation and repair strategies
- specifies the standard of report presentation that is acceptable to NR&M.

This advice is intended to define a minimum standard of report. It would be expected that engineers experienced in the management and performance of dams would provide a dam owner with comment and insight into the issues that are influencing the safety of a dam and advice on the management of the dam as an asset.

While most of the common causes of dam failure have been included in here, the list is not inclusive. Each dam is different and may present its own unique problems. Anyone who inspects dams should be aware of a wide range of potential problems and look for all potential modes of failure.

Where a dam contains novel or particularly complex features the inspection and report should reflect additional emphasis on these aspects.

Part A - Periodic Inspections

Periodic Inspections focus on the physical defects.

Personnel

For safety reasons it is advisable to have two or more personnel on each inspection. This applies particularly to isolated areas and to inspections where access to confined spaces is necessary.

Equipment

The following items may be useful

- checklist field book and pencils
- recording device (eg dictaphone)
- cameras (still and video)
- hand held levels
- probe
- safety gear: waders, harnesses, hard hats, safety boots, breathing apparatus, flame safety lamp and anything else to comply with safety regulations
- tape measures

- torch ("mine safe" for unventilated conduits, tunnels or adits)
- shovel
- geological hammer
- binoculars
- first aid kit
- stakes and flagging tape.

Recording Inspection Observations

Inspections require the accurate location, recording and photographing of questionable areas. The objective is to permit observation and comparison of the state of a dam through time. It is necessary to record:

- extent of such areas (ie length, volume, width and depth or height)
- a brief description of any anomalous condition eg:
  - quantity/quality of drain outflows, seepage and its source(s)
  - location, type and extent of deteriorated concrete
  - location, length, displacement and depth of cracks
  - extent of moist, wet or saturated areas
  - changes in conditions.

Areas For Inspection

Monitoring

A surveillance evaluation should be integrated into a periodic inspection. The surveillance evaluation report should:

- assess the available pressure, movement and seepage monitoring data by analysis of the impact (if any) of all monitoring results
- assess the seepage from the storage (A plan should be provided showing position, quantity, and quality of seepage.)
- report on the recent movement survey for the dam
- report on the foundation and embankment pressures being experienced by the dam (A plan showing the position and purpose of the individual piezometers should be provided).

An assessment should be made of the appropriateness of seepage, movement and pressure monitoring being carried out at the dam.

Operation

The report should include a review of the way in which the dam has been operating since the last periodic inspection and how it is intended to operate until the next periodic inspection is carried out. The report should comment on the impacts of the operation on dam safety including rainfall records, release records, record of flows in the spillway and maintenance and repairs carried out.

It is appropriate to report on the compliance with Standard Operating Procedures (SOP). It is also desirable to assess the SOP relative to best practice and the Queensland Dam Safety Management Guidelines 2002.

Requirements for specific elements of dams are outlined in Part E.

The following areas may also have to be considered in an inspection;

- a test operation of all equipment
- evaluation of all surveillance data
- major function checks and maintenance inspections. For example:
  - flip bucket watering
  - conduit dewatering
  - diver inspection of intake work
  - conduit video inspection
- the foundations, abutments, and reservoir rim should all be inspected regularly
- an inspection should be made far enough downstream to ensure that there are no problems that will affect the safety of the dam
- the reservoir surface and shoreline should also be regularly inspected to identify possible problems. whirlpools can indicate submerged outlets (Large landslides coming into the reservoir could cause waves overtopping the dam or water quality problems, suspect areas should be quantitatively monitored.)
- upstream development and other catchment characteristics, which might influence reservoir water or silt inflows, should be noted in major inspection reports to anticipate possible problems or modifications in the dam
- downstream development in flood plains should also be regularly assessed.

Part B - Special Inspections

A Special Inspection is recommended in the following cases regardless of the regular inspection schedule:

- whenever a concerning specific defect is observed in the dam
- during and immediately after the first reservoir filling or augmentation
- during and after a rapid draw down
- before a predicted major rainfall, or filling
- during (if possible) and after heavy flooding (or severe windstorm)
- following an earthquake, sabotage or overtopping; immediately and then regularly for several months to detect any delayed effects.

When carrying out a Special Inspection a dam owner should follow the steps listed for Periodic Inspections.

Part C - Comprehensive Inspections

Comprehensive Inspection focuses on the dam safety management program and documentation for the dam. It is an assessment of the appropriateness, the effectiveness and application (including the owner's response to recommendations) of the dam safety management program and documentation for the dam including:

- SOPs
- DOMMs
- EAP
- Data Book
- Design Report/Safety Review
- Surveillance and inspection program and records.

This assessment should take into account the development permit conditions for the dam.

Personnel

An experienced dams engineer who is a RPEQ should carry out Comprehensive Inspections. In assessing and reporting on these aspects of the dam the inspecting engineer needs to assess the current dam safety management program and documentation for the dam against that required firstly, in the development permit conditions and generally in the Queensland Dam Safety Management Guidelines 2002.

Operation

It is appropriate to report on the compliance with SOPs. It is also desirable to assess the SOP relative to best practice and the requirements of the Queensland Dam Safety Management Guidelines 2002

Inspection

Comprehensive Inspections should incorporate a review of the Periodic Inspection program and periodic inspection records for the dam as well as evaluating the dam owner's response to the conclusions and recommendations from inspection reports.

Emergency Preparedness

Comprehensive Inspections should incorporate an assessment of the emergency preparedness of the owners and operators of the dam. The owners EAPs and documentation should be assessed relative to the requirements of the Queensland Dam Safety Management Guidelines 2002.

Part D - Preparation of a Periodic, Special And Comprehensive Inspection Report

General

The aim of the periodic, special and comprehensive inspection reports is to document the findings of each inspection and to detail the required actions to be taken by the owner as a result of the inspection. These reports should be presented in a precise and readable form and be signed by the inspector.

Detailed data that is used to assess aspects of the dam should be attached as appendices and not included in the body of the reports. Captioned and dated photographs should be used extensively in the reports.

Information On The Dam

The report should include the following background information on the storage:

- ownership details including any change of owner
- details of the development permit conditions for the dam
- a brief description of the dam including:
  - location (latitude and longitude)
  - nearest town
  - principal dimensions and design water levels
  - construction type
  - current water levels
  - history, including inspection history.
- a thorough and critical review of:
  - Data Book

- SOPs
- EAPs
- operation and maintenance plans and log books for the dam
- Safety Review status for the dam.

Documenting The Inspection

The report should address the preparation for the inspection in the following areas:

- outline of the preparation for the inspection
- the preparation of checklists
- data gathering
- special provisions (eg drainage of stilling basins or aerial inspection)
- review of previous inspection, including identification of action items
- review of operation and design information.
- composition of the inspection team including:
  - details of the inspecting engineer or consultant including the RPEQ No. as appropriate (RPEQ No. compulsory for comprehensive inspections)
  - details of owner's representative
  - detils of operations staff involved in the inspection
- the photographic record of the inspection. All photographs should be dated and annotated to reflect the features recorded

Conclusions And Recommendations

Each inspection report should include an overall assessment of the state of the dam and recommend action to remedy defects or ensure continued appropriate management practices. These should include:

- comments on the implementation of recommendations from previous reports
- conclusions on the safety of the dam
- recommendations on additional evaluation, investigation or testing
- recommendations on rehabilitation, repair and operational modifications relating to issues that were noted during the inspection
- a summary sheet outlining the recommended action, the responsible person and the appropriate time frame
- the dam owner should sign the report and endorse the recommendations.

If observed defects are considered serious, advice from a suitably qualified and experienced engineer should be sought. Depending on the significance of the potential consequences, the advice should be documented in the report.

Circulation

Copies of the periodic inspection report should be circulated to the following:

- the dam owner
- the individual responsible for operation of the dam.

Copies of the comprehensive inspection report should also be circulated in accordance with the development permit conditions for the dam.

Sample Contents Page

- General
- Conclusions and Recommendations
- Information on the dam
- Inspection
- Monitoring
- Review of Data Book, SOPs, DOMMs & EAP *for comprehensive inspections
- Embankment (If Needed)
- Spillway
- Outlet Works (If Needed)
- Concrete (If Needed)
- Weir
- Captioned and Dated Photographs

Part E - Requirements for specific elements of dams for Periodic, Special And Comprehensive Inspections

This section outlines defects observed in each of the following elements of dams.

1. Earth embankments
2. Spillways and bywashes
3. Discharge control structures and outlet works
4. Concrete dams
5. Weirs

Owners should address the requirements for each element of their dam.

1. Requirements for earth embankments

There are several types of dam construction that are included in the earth embankment category. They include:

- homogeneous rolled earth fill dams
- homogeneous rolled earth fill dams with toe drains
- zoned rolled earth fill dams
- diaphragm rockfill dams
- central core rockfill dams.

These dams all include an impermeable zone of clay fill or concrete and a supporting rock or earthfill zone to provide strength. Filter zones provide internal drainage of the structure.

These dams can fail by:

- internal erosion of embankment material by seepage and transport of embankment material through sinkhole cracks, animal burrows, compaction flaws in embankment, compaction flaws in conduit surrounds, flaws in the abutments (known as a piping failure)
- bulk removal of material and loss of height and section through slumping, beaching, tree blow over, and gully and sheet erosion
- overtopping.

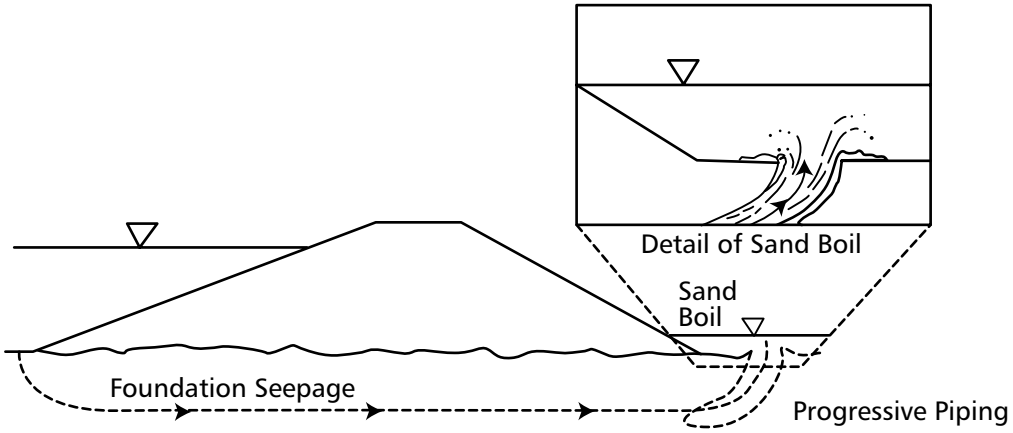
The report should document the inspection by including comments on the condition of the dam embankment with regard to

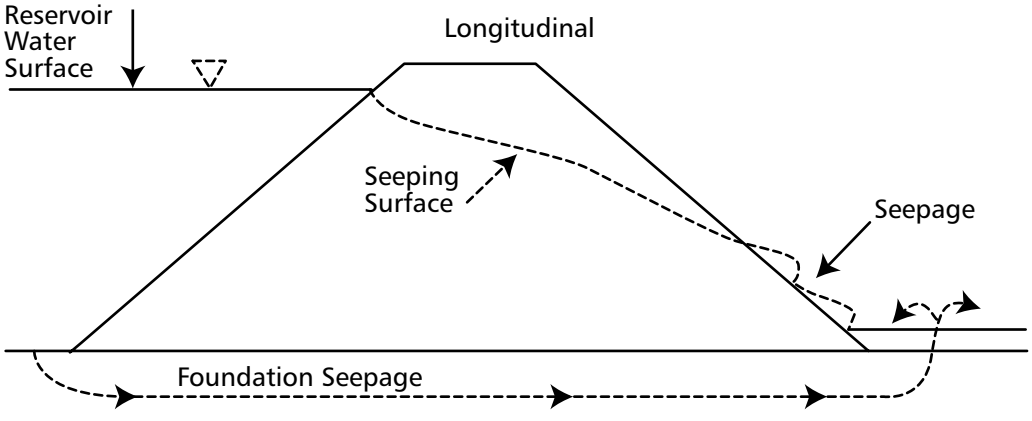
- erosion
- vegetative growth
- seepage
- slump formation
- beaching
- deterioration of rip rap
- cracking.

Following are some illustrations of deficiencies to look for when inspecting embankment dams.

Seepage

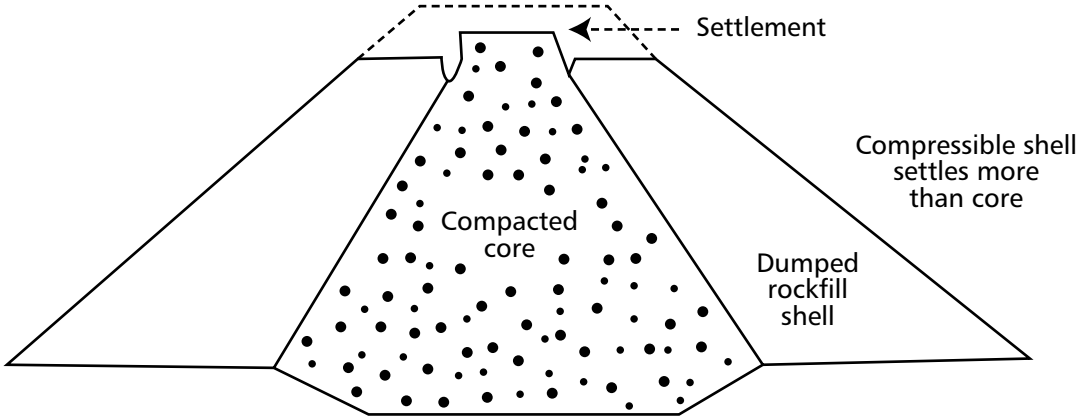
- A water flow or sand boil on the lower portion of the downstream slope or toe area, especially at the groins.
- Leakage around conveyance structures such as outlet works, spillway conduits, or penstocks.
- Blocked toe drains and relief wells.
- An increase in the amount of water being released from toe drains and relief wells. (Remember to take into account changes in the reservoir level, or the effects of rainfall on the downstream face and abutments).
- Wet areas or area where the vegetation appears greener or more lush on the embankment slope or toe area.
- Turbidity or cloudiness of the seepage.

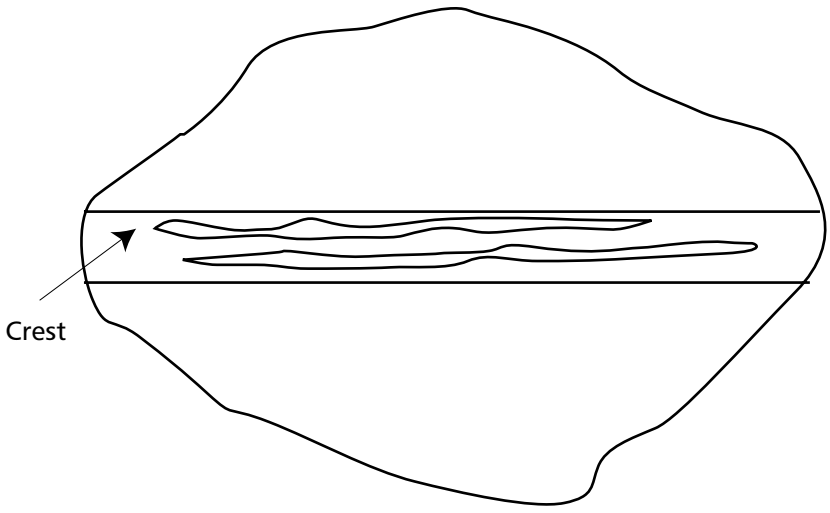




Cracking

- Desiccation Cracking: A random honeycomb pattern of cracks usually found on the crest and the downstream slope.
- Transverse Cracking: Cracks that are perpendicular to the length of the dam usually found on the crest.
- Longitudinal Cracking: Cracks that are parallel to the length of the dam. Longitudinal cracks may be associated with stability problems in the slopes.

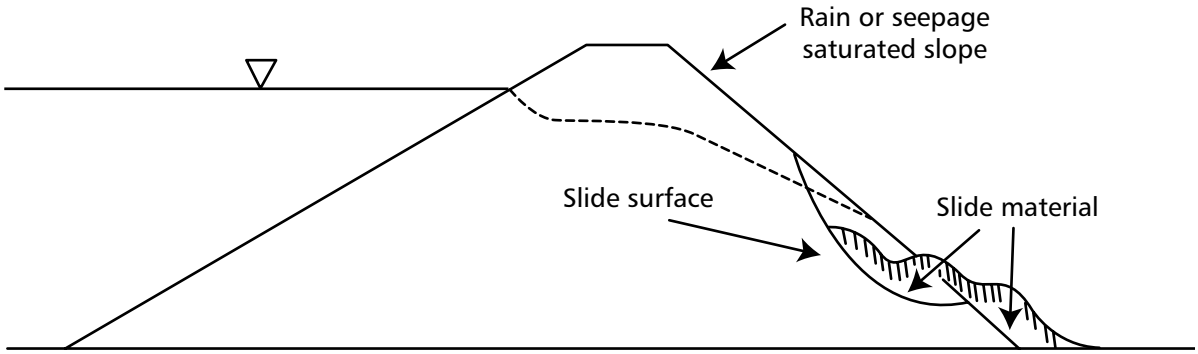


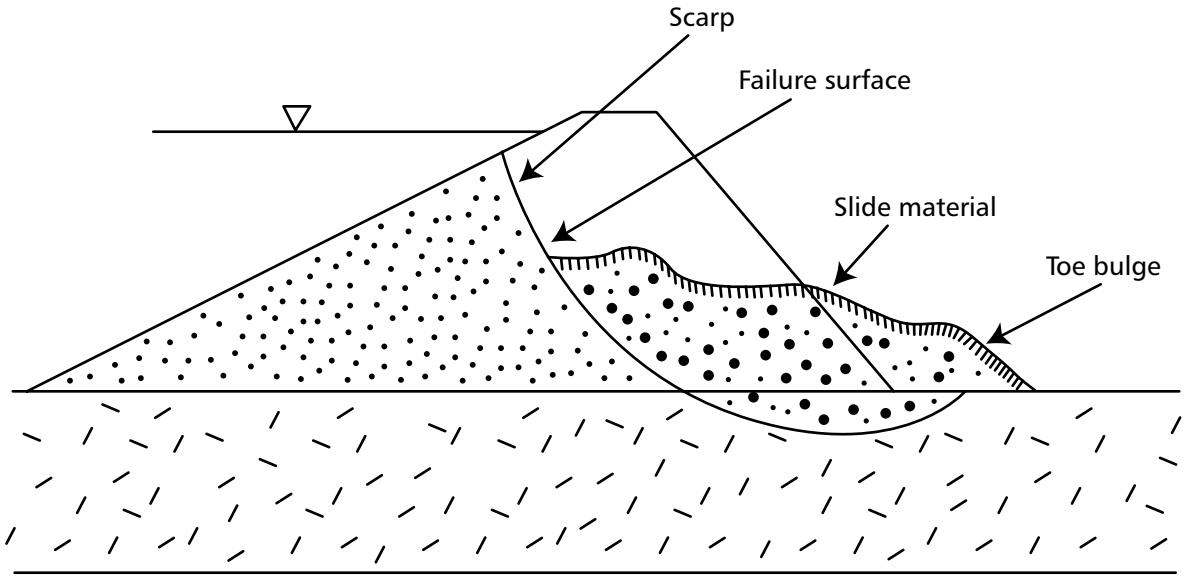


Plan view

Instability

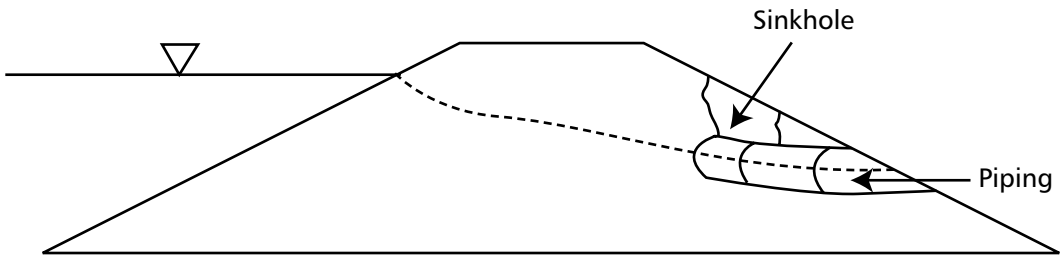
- Slides on the upstream and downstream slopes.
- Bulging, especially at the toe of the dam.
- Misalignments in the crest and embankment slopes found by sighting along fixed points.





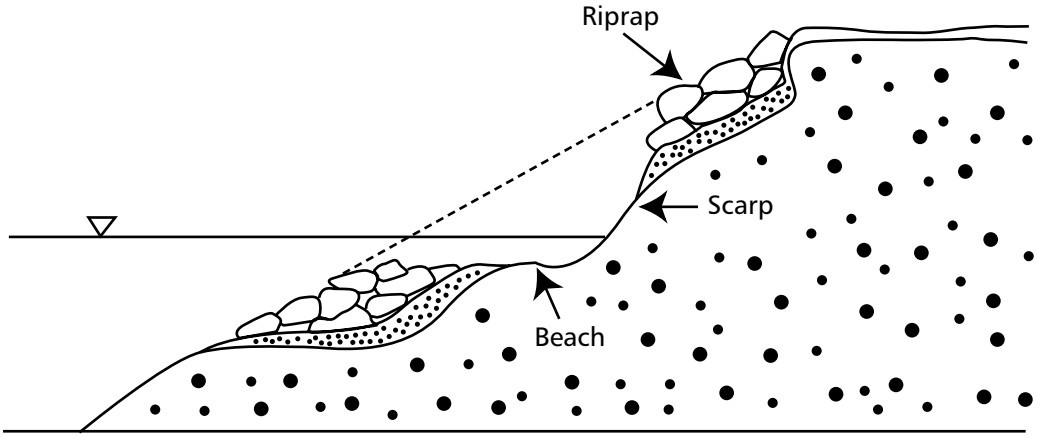
Depressions

- Sinkholes found by checking and probing each depression. Remember, sinkholes have steep, bucket-like sides while minor depressions have gently sloping, bowl-like sides. These are initiated by settlement or migration of materials in the embankment.



Maintenance Concerns

- Inadequate Slope Protection: Check for bald areas or areas where the protection is sparse or damaged.
- Surface Runoff Erosion: Check for gullies or other signs of erosion. Make sure to check the low points along the upstream and downstream shoulders and groins since surface runoff can collect in these areas.
- Inappropriate Vegetative Growth: Check for excessive and deep-rooted vegetative growth, especially trees.
- Debris: Check for debris on and around the dam, especially debris that could clog or choke outlet-works or spillway inlets.
- "Animal Burrows": Check for damage caused by burrowing animals.



2. Requirements for spillways and bywashes

Spillways are designed to withstand high flows that have the capacity to overtop and erode embankments and to undermine concrete and rockfill structures.

Spillways that are not able to adequately contain the extreme flows through the dam contribute to failure of the dam by overtopping.

Spillways can fail by erosion of the structure from downstream, and by erosion that results from failing to contain the flows within the spillway section and by erosion of support for any structural elements through weaknesses.

Spillway flow needs to be directed back to the stream safely. Poorly directed flows through the spillway can erode the toe of the dam embankment and initiate failure.

Spillways and bywashes should be inspected immediately after spill events to monitor any damage and to determine erosion patterns. Comments on damage sustained after spill events should be included in the surveillance report.

The surveillance report should include an assessment of, and recommendations on the dam spillway or bywash with regard to:

- erosion of the downstream slope
- slumps in sidewalls
- potential for blockages caused by fencing, debris build up, or vegetative growth
- profusion and integrity of grass cover to the downstream slope

- blockages in the underdrainage of concrete spillways.

A recommendation for any remedial works to ensure the spillway and bywash is capable of fulfilling its function.

3. Requirements for discharge control structures and outlet works

Dams with inadequate and failed outlet pipes experience loss of serviceability by emptying or by being unable to release as required. Leaking from the outlet conduit is a common source of internal erosion failure. Deterioration and failure of the outlet structure, collapse or deterioration of the outlet pipework or valves or failure of associated control systems could cause the loss of outlet capability.

Discharge conduit

The discharge conduit should be inspected internally if possible (proper regard for workplace health and safety requirements is essential). If access to the conduit is not possible, video inspection should be carried out. The following aspects of the conduit should be assessed and reported on:

- sources of leakage should be photographed, marked on a plan and the flow rate estimated
- misalignment should be measured, and marked on a plan
- deterioration of pipe and joint material should be photographed
- fouling of the intake structure
- extent of corrosion.

Valves

All valves should be exercised at each inspection and an assessment made on the condition, the ease of operation, maintenance history and ease of access. The report should contain comments on the appropriateness of labelling of valves.

The full range of gate settings should be checked. The person performing the inspection should slowly open the valve, checking for noise and vibration. Certain valve settings may result in greater turbulence. There is a need to also listen for noise like gravel in the system. This indicates cavitation is occurring, and these gate settings should be avoided.

Structures

All structure associated with the dam should be assessed for serviceability. Intake structures may need to be inspected by divers for fouling and deterioration. Valve pits and boxes inspected for concrete deterioration and settlement. Intake structure steelwork inspected for corrosion and misalignment and damage. Baulks and gates exercised and inspected for corrosion and damage. Outlet structures inspected for concrete deterioration corrosion and misalignment and damage.

Dams incorporating mechanical or fabridam gate structures should be reported on by an appropriately experienced mechanical engineer.

Electrical, mechanical and control systems

Mechanical equipment including spillway gates, sluice gates, valves, stoplogs, pumps, flash boards, relief wells, emergency power sources, siphons, and electrical equipment should be operated at least once a year and preferably more often. Testing should cover the full operating range under actual operating conditions. Each operating device should be permanently marked for easy identification, and all

operating equipment should be kept accessible. All controls should be checked for proper security to prevent vandalism. All operating instructions should be checked for clarity and maintained in a secure, but readily accessible location.

All control systems associated with operation of the dam should be reported on by an appropriately experienced electrical engineer. The report should include assessment of the operation of all functions of the control system through the full range of responses and alarms. The report should incorporate an assessment of the condition and the maintenance and operation history of the system and of the existence and appropriateness of the operation plan for the controlled system. The report should make recommendations on the future maintenance requirements.

4. Requirements for concrete dams

Possible causes of concrete dam failure include:

- overturning or sliding due to erosion of the foundation or abutments during overtopping resulting from inadequate freeboard
- abutment or foundation failure due to overstressing
- structural failure of concrete unable to sustain imposed loads.

When inspecting the crest and the faces of concrete dams and weirs any of the following defects should be noted, documented and photographed and an assessment made of any changes in their severity since last inspection:

- seepage and leekage
- cracking concrete deterioration
- disintegration
- spalling
- efflorescence
- drummy concrete
- popouts
- pitting
- scaling
- surface defects
- displacement
- misalignment
- differential movement in cracks
- conditions of joints.

When inspecting the areas upstream and downstream of a concrete dam and weirs any of the following defects should be noted, documented and photographed and an assessment made of any changes in their severity since last inspection:

- cracking, bulges and slides
- sinkholes
- wet areas
- lush vegetation
- erosion of the abutment areas following spills.

5. Requirements for weirs

Weirs are designed to withstand overtopping by all river flows. As a consequence, weirs need to not only be stable and safe against the hydraulic forces applied and to retain water but must also be able to retain integrity in an erosive environment.

Whilst a regular time based inspection regime is appropriate, it is more important to inspect and document the deficiencies and remedial requirements after each river flow event.

Common causes of failure of weirs include:

- excessive and progressive downstream erosion, both from within the stream and through lateral erosion of the banks
- erosion of inadequately protected abutments
- hydraulic removal of fines and other support material from downstream protection (gabions and aprons) resulting in erosion of the apron protection
- deterioration of the cutoff and subsequent loss of containment
- additional aspects specific to concrete, rockfill or steel structures.

Inspection reports should comment on:

- details of any testing of flow control structure
- adequacy of flow control structure
- Mechanical / electrical equipment
- disruption to the downstream banks - as an indication of erosion
- water levels in the downstream pond - as an indication of seepage
- deepening of the downstream pond as a result of erosion
- erosion of abutment protection
- corrosion or other deterioration of the sheetpile or other cutoff material
- cracks and open construction joints in the downstream apron - as an indicator of hydraulic removal of fines.

Inspection reports for weirs should document the:

- magnitude of each river flow event since last report
- comment on the relative upstream and downstream water levels
- any repairs and maintenance resulting from each flow event
- comments on the operation of mechanical equipment (eg gates, bags) during flow events.

Notes

Notes

DEPARTMENT OF NATURAL RESOURCES AND MINES

QUEENSLAND DAM SAFETY MANAGEMENT GUIDELINES

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