

### Dam Safety Inspections...

#### A Closer Look

#### Introduction

Safety inspections are an important and necessary responsibility of dam owners. The goal of a safety inspection is to identify potential dam safety deficiencies before they become dam safety incidents. If not corrected, these deficiencies can turn into serious, costly repairs or even dam failures. Dam inspections are also a great opportunity to gather the owners, engineers, experts, regulators and all stakeholders involved with a dam in order to educate, communicate, to delegate responsibilities, to discuss possible failure modes, to plan for emergencies, and to establish long term relationships concerning the dam. This article is intended to be a high level overview of the safety inspection process for small low-hazard dams from planning to implementation. For additional details regarding dam safety inspections, the reader is encouraged to visit the Association of State Dam Safety Officials (ASDSO) website and view the webinar titled, [Introduction to Inspecting Dam for Owners and Operators](#).

#### Why are Inspections Important?

During an inspection of an emergency spillway, an inspector identified open, unsealed joints between concrete spillway slabs (Photo 1).



Photo 1: Concrete spillway from the inspection report. Photo inset shows an open joint.

The openings were as wide as 1 inch and had vegetation growing in them. A recommendation was made in the inspection report to repair the joints, but the dam owner neglected to implement the repair.

Four years later the spillway operated and the water flowed into the open, unsealed joints causing uplift pressures to develop beneath the slab that ultimately led to the failure of the spillway slabs (Photo 2). It cost the owner more than \$1.25 million to reconstruct the spillway. The spillway failure may have been averted if the owner had implemented the repairs recommended in the inspection report. The cost to implement the inspector's recommendation was estimated to be approximately \$500.



Photo 2: Failed concrete spillway following operation during a storm event.

#### Types of Inspections

Typically dam safety organizations and dam owners will conduct a variety of inspections including formal, intermediate, routine, and emergency inspections. Regulatory requirements, hazard classification, dam condition, and special events dictate the scope and frequency of dam inspections. A qualified engineer is required for formal, intermediate, and emergency inspections. Due to safety concerns, some inspection activities may need to be performed as a team or with the aid of specialized equipment. For example, inspections of the conduit may require confined space entry protocols or a remote operated vehicle (ROV). A detailed discussion about conduit inspections was presented in a previous article titled, [You Con-du-it: How to Fix a Leaky Pipe](#).

#### Who can be an inspector?

People who have:

- Good knowledge of the design, operation, maintenance, and potential failure modes of the dam.
- The physical capability to



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traverse rough terrain, steep slopes, remote locations, and long distances.

- Keen observation skills.
- Willingness and motivation to get dirty and wet!
- Good documentation and report writing skills.

### Preparing for Your Inspection

The inspection begins long before arriving on site. The well-prepared inspector begins by becoming familiar with site access, design features, construction history, inspection history, and even the type of weather that may be encountered during the inspection.

**Assemble Inspection Team** – Review the previous inspection reports to see if an additional engineer with structural, geotechnical, or hydraulic experience may be needed to round out the inspection team.

**Contact Regulatory Agency** – It is worth a quick phone call to the appropriate oversight agency to verify regulatory requirements for inspection (such as a mandatory outlet inspection or concrete condition survey).

**Review Recent Weather** – Pondered water may not always be a sign of potential seepage. Knowing if the site has recently experienced precipitation events may give the inspector important clues during the inspection.

**Review Previous Checklists** – Become familiar with what previous inspectors have identified, repairs that have been recommended, and status of completion.

**Review Drawings or Construction Documentation** – Understanding how the dam was designed or constructed can help identify where potential problems may exist. Note the locations of drainage outlets and instrumentation.

**Review Potential Failure Modes** – Reviewing the potential failure modes specific to your dam will help focus your efforts on specific components of the dam.

**Coordinate with Owner/Operator** – Discuss with the owner in advance any activities that can be undertaken to make your inspection more efficient. Can a survey be performed to evaluate differential movement or settlement of structures? Does the stilling basin need to be dewatered? Can the owner operate through the full gate range? Do they need to notify water users of an impending gate closure? What about mandatory

minimum releases – will someone get in hot water if you temporarily dewater the stream? Request seepage weirs be cleaned to collect accurate readings. Request that tall grasses and vegetation be removed prior to inspection. It's a lot easier finding a crack or an animal burrow when you're not staring through 3- to 4-foot tall grass (Photo 3)!



Photo 3: The importance of mowing before an inspection.

**Review Instrumentation Data** – Piezometers and seepage weirs are the first indication that something may have changed. Print out in advance a location map, simple plots, and key information for each piezometer to take with you. Having this information available will help you during the inspection. It's a perfect opportunity to make sure that your survey points haven't walked off with the public.

**Assemble Necessary Equipment** – It is very important to plan out what equipment you may need for an inspection before you get there, especially if your dam is remote! Equipment may include all or some of the following (Photo 4):



Photo 4: Typical inspection equipment.

- Inspection form ([click here for more information](#)), notebook, clipboard, pencil
- Camera, GPS, cell phone, rangefinder

- Hand level & rod, binoculars, probe (old ski pole)
- 100' tape, 25' tape, 6' folding rule, measuring wheel
- Flashlight and/or mirror
- Bucket and timer (to measure seepage rate)
- Stakes, flagging, poke stick
- Aerial photo of inspection area
- Rubber boots, snake chaps, sunscreen, insect repellent, Bear Spray, First Aid Kit, sensible clothing for weather
- Drinking water, food
- Rubber hammer
- Outlet inspection camera and sled, a Do-It-Yourself (DIY) camera and sled was included in a previous article titled, [You Con-du-it; How to Fix a Leaky Pipe](#)
- Confined space entry equipment and paperwork
- An experienced yet open and creative mindset

**Assemble Documentation** – Documentation may include a map or drawings of the dam and the inspection form. Below is a list of some other documentation that may be useful:

- List of potential failure modes
- Previous inspection checklists
- Old construction photos
- Plots of instrumentation data
- List of previous repairs or modifications and repair recommendations
- The dam's electronic project file (if available), loaded on a tablet for reference, if needed
- Talk to last year's inspector about problems or issues and document.

### General Inspection Guidance

The purpose of an inspection is to observe every part of a dam and its appurtenant structures to identify changes between inspections. Performing inspections by the same person, during the same time of year under the same type of reservoir loading has advantages and disadvantages. For example, it is important to inspect a dam when the reservoir is at a similar level as the previous inspection to confirm observed seepage is similar to previous inspections. However, there are also advantages to inspecting the dam during different seasons with different people and during different reservoir levels. A late season

inspection often provides the inspector the opportunity to see the upstream face of the dam...a good opportunity to look for sinkholes, as described below. If the dam has piezometers, arrangements should be made to measure the static water level during the inspection (preferably at full pool). The inspector(s) may need to have a bit of flexibility in their schedule(s) to see how the dam responds to varying or similar conditions.

**Terminology** – Make sure to use accurate dam terminology. It's better to use upstream and downstream, left and right – typically facing downstream, instead of using compass directions. Providing clear definitions for good, fair, and poor condition is also important for future inspectors to understand how the condition was assigned.

**Use the SIMPLE Rule** – For documenting defects, **S**ketch the location of the defect, **M**easure the defect (depth, width, length), **P**hotograph the defect, **L**ocate the defect in reference to a known location (use existing stationing or measure from a known feature like the outlet works or spillway).

**Photo Tips** – Consistency: Take photos at the same location and orientation as previous photos. Using a scale in the photos helps document size and/or extent of the feature being documented. Photos can be used for comparison if conditions change.

**Zigzag vs. Parallel** – These are two methods primarily used to inspect a dam: zigzag or parallel (Figure 1). Typically, the zigzag method can be used on small dams by inspectors who are physically fit. The parallel method is useful for steep or rocky slopes. For both methods, it is important to make sure that the inspector stops periodically and turns 360° to observe the slopes near and far for anything unusual before continuing on the inspection.

**Teamwork** – If inspecting with two people, develop a system so that one person is taking photos and keeping the photo log and the other person is measuring and documenting observed conditions. The person with the gym membership can be the one to hike up and down the slopes while the other walks along the crest.

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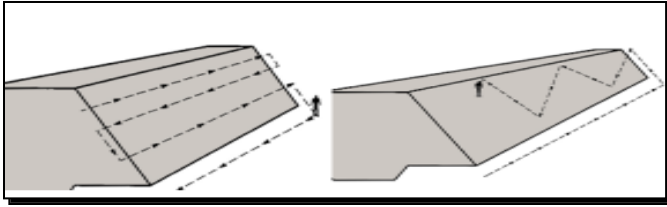


Figure 1: Inspection methods typically follow a zigzag or parallel method.

### What Should I Look For?

Safety inspections will cover every visible portion of the upstream and downstream slopes, crest, auxiliary spillway, outlet conduit, outlet structures, and reservoir rim. Although all inspections are comprehensive in nature, the scope of the inspection depends on the type of inspection being performed (e.g., formal vs. intermediate vs. emergency). For inspection tips and guidelines specific to outlet conduits, see the previous article titled, [You Con-du-it; How to Fix a Leaky Pipe.](#)

The following sections present some typical deficiencies noted during dam safety inspections and possible causes and consequences.

### Upstream and Downstream Slopes

#### Slide/Slump/Slip (Deep or Shallow):

- Causes: Originated as cracking excessive erosion, over steepened areas, saturation, rapid drawdown
- Consequences: Crest loss and overtopping; shortened seepage path

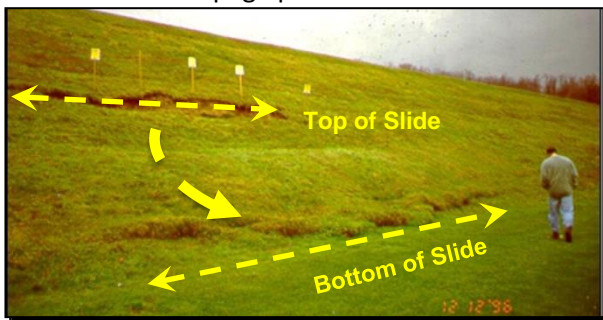


Photo 5: Shallow slide, slump, and slips on a slope (ASDSO)



Photo 6: Deep slide, slump, and slips on a slope (ASDSO)

#### Sinkhole:

- Causes: Embankment material carried through erosion pipe, collapse of material into animal burrow
- Consequences: May represent a serious piping problem in embankment or foundation

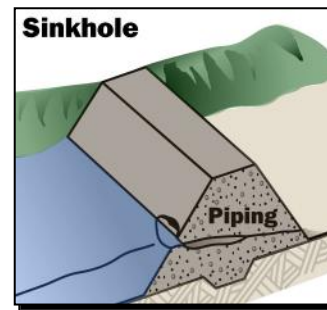


Figure 2: Sinkhole on slopes (AECOM)



Photo 7: Sinkhole on downstream slope (AECOM)

#### Broken Down/Missing Riprap and Slope Erosion:

- Causes: Poor quality riprap has degraded, undersized riprap displaced by wave action
- Consequences: Erosion, loss of crest, overtopping

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Photo 8: Loss of riprap and slope erosion (Montana DNRC)

### Slope Erosion:

- Causes: Rain, snow melt, ponding on crest, poorly maintained crest, vehicles/animal trails, sparse vegetation
- Consequences: Erosion can create gullies, which lead to over steepened area and stability issues



Photo 9: Slope erosion and sparse vegetation (AECOM)

### Animal Burrows:

- Causes: Water and vegetation attract wildlife
- Consequences: Preferential seepage paths, erosion, and loss of freeboard



Photo 10: Animal burrow (Montana DNRC)

### Crest

#### Desiccation/Transverse/Longitudinal Cracking:

- Causes: Clay material shrinks as it dries, differential settlement of embankment or foundation, weak embankment material, slide
- Consequences: Shortens preferential seepage path, seepage paths through cracks can lead to internal erosion, slides



Photo 11: Transverse crest crack (ASDSO)



Photo 12: Longitudinal crest crack (Montana DNRC)

#### Sinkhole:

- Causes: Collapse of embankment material into piping hole or animal burrow, settlement over outlet works conduit
- Consequences: Could represent serious piping problem in the embankment leading to failure



Photo 13: Crest sinkhole (ASDSO)

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### Low Crest Areas:

- Causes: Settlement, early signs of piping or a void, erosion, poor construction/maintenance
- Consequences: Reduced freeboard can lead to overtopping and failure



Photo 14: Low crest areas (Montana DNRC)

### Vegetation:

- Causes: Poor maintenance, excessive water promotes growth
- Consequences: Obscures inspection, tree roots can cause seepage paths, large trees can blow over and their root systems can dislodge soil and reduce freeboard



Photo 15: Crest vegetation (AECOM)

### Ruts:

- Causes: Vehicle traffic, poor maintenance, poor drainage
- Consequences: Seepage into embankment from ponded water, loss of freeboard



Photo 16: Crest ruts (ASDSO)

### Seepage

Since seepage can occur through the embankment, foundation, abutments, or along embankment penetrations, this topic will be addressed separately.

#### The most common seepage locations:

- Downstream slope and toe
- Foundation downstream of embankment
- Abutment groins
- Penetrations through embankments

#### Look for:

- Areas of green, lush/wetland vegetation
- Abrupt changes or horizontal lines of vegetation
- Flowing water
- Turbid, cloudy, or muddy water

#### Sandboils:

- Causes: Seepage through foundation removes material, high seepage velocities cause sand to "boil"
- Consequences: Continued seepage and erosion can lead to sinkholes and foundation failure and can eventually cause embankment failure



Photo 17: Sandboil (ASDSO)

#### Cloudy Seepage:

- Causes: Piping or internal erosion, internal crack, pervious zone, or animal burrow; poorly compacted contact between embankment and abutment, seepage occurs in abutments
- Consequences: Progression of piping and erosion of material, failure, abutment slide

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Photo 18: Muddy seepage at downstream toe (ASDSO)

### Spillways

Open or displaced joints on the spillway walls and slabs can allow uplift pressures to develop as described earlier (Photos 1 and 2).

#### Obstructions:

- Causes: Vegetation, floating reservoir debris
- Consequences: Reduced spillway capacity can lead to overtopping



Photo 19: Vegetation obstructing spillway flow (AECOM)

### Outlet Structures

#### Concrete Spalling, Honeycomb, Erosion:

- Causes: Erosion from water, poor construction, freeze-thaw action
- Consequences: Rough concrete will erode faster; exposed rebar may cause internal corrosion



Photo 20: Concrete erosion (AECOM)

#### Damaged Gate or Operator:

- Causes: Broken support block, bent/broken control stem, debris stuck under gate, cracked gate leaf, damaged gate seat or guides, missing limit nut, improper operation (discuss with dam tender)
- Consequences: Inability to close gate reduces water storage, inability to open gate compromises ability to draw down reservoir in an emergency



Photo 21: Bent gate stem (AECOM)

#### Erosion/Undermining:

- Causes: Undersized riprap or loss of riprap, no energy dissipating structure at outlet
- Consequences: Instability of outlet structure, progressive backward erosion into the downstream slope

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Photo 22: Erosion and undermining of outlet structure (AECOM)

### Reservoir Rim

#### Landslide Susceptibility:

- Causes: Reservoir water surface increases water level in weak materials in the abutments and surrounding hillsides cause landslides or slope instability
- Consequences: Reduced storage capacity, blocking or damage to intake structure

### Inspection Closeout

Before you leave the dam site and begin a long drive back:

- Read through checklist and notes. Are you missing any information? Did you forget to walk an area?
- Are you missing any photos that you thought you took?
- Did you forget to measure seepage or anything else?
- Completely fill out the checklist. Do not be tempted to leave the site before completing this task.
- Kick the dirt or hang out on the pickup hood or tailgate 'office' with the owners for a while longer. The longer you stay the more they will tell you of the real history, maintenance, issues, and problems with a dam and the longer you have to instill some dam safety wisdom. Remember dam safety is about building lasting and trusting relationships with owners and stakeholders. It is not just a short term visit followed by a nasty letter. It is a long term relationship with people.

Now that you are back to civilization, prepare your inspection report:

- Try to write the inspection report as soon as possible before you start to forget details!
- Save photographs and add captions to those that are significant.
- Finalize checklist and prepare a sketch of the dam showing observations/problem areas.
- Compare your observations with previous reports.
- State status of recommendations from previous inspection (e.g., completed, incomplete, deleted), carrying forward incomplete recommendations.
- Make recommendations for maintenance and/or repairs.
- Recommendations should be specific and concise; use accurate terminology, state a time frame for implementation, and have a cost estimate, if applicable.
- Share inspection report with other team members and request their input and review.
- When required, inspections should be submitted to the appropriate regulatory agency following inspection completion.
- Follow up with all stakeholders early and often during the year to discuss issues or to emphasize solutions and strengthen relationships.

### Useful References

- [1] [Association of State Dam Safety Officials. \(2013\). Introduction to Inspecting Dam For Owners and Operators](#)
- [2] [United States Department of Homeland Security: Federal Emergency Management Agency. \(2004\). Federal Guidelines for Dam Safety, FEMA 93.](#)
- [3] [Association of State Dam Safety Officials. Responsible Dam Ownership: Operation, Maintenance and Inspection.](#)
- [4] [United States Department of Homeland Security: Federal Emergency Management Agency. \(2007\). Training Aids for Dam Safety \(TADS\): A Self Instructional Study Course in Dam Safety Practices, FEMA 609DVD.](#)
- [5] [United States Department of the Interior: Bureau of Reclamation. \(2000\). Safety Evaluation of Existing Dams \(SEED\): A Manual for the Safety Evaluation of Embankment and Concrete Dams.](#)
- [6] [United States Department of Agriculture: Natural Resources Conservation Service. \(2014\). Formal Dam Inspection Checklist, WV-ENG-105.](#)

### Example Checklists

[Montana Example Checklist](#)

[Colorado Example Checklist](#)

[Wyoming Example Checklist](#)

[Association of State Dam Safety Officials](#)