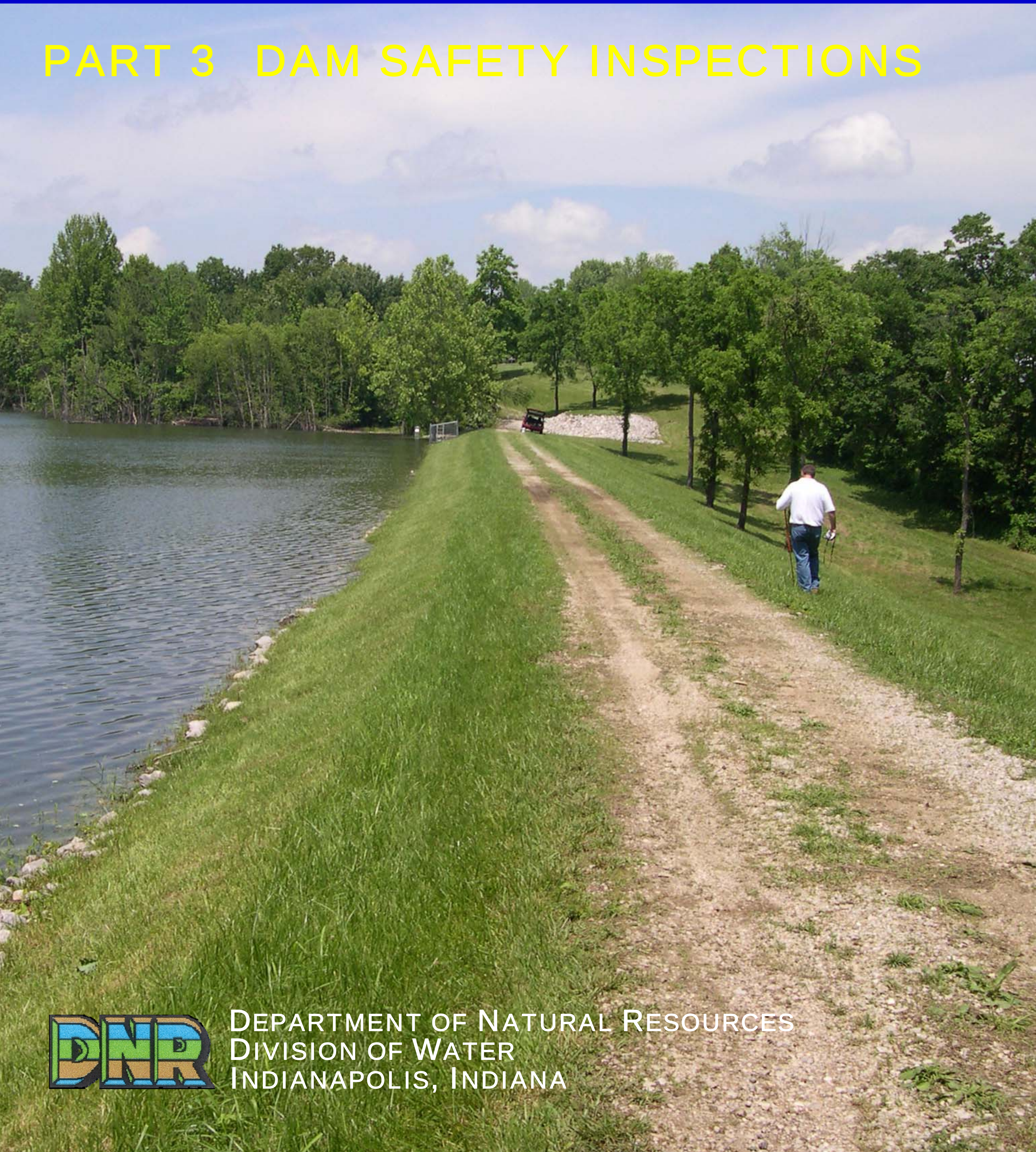
INDIANA DAM SAFETY INSPECTION MANUAL

UPDATED 2007

PART 3 DAM SAFETY INSPECTIONS



DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER
INDIANAPOLIS, INDIANA

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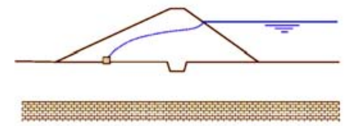

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Preface – Part 3

The Indiana Dam Safety Inspection Manual is based on accepted practice and consists of information developed from existing documentation on dam safety inspections obtained from state and federal agencies. Dam safety is a complex and multi-disciplinary practice that continues to evolve as professionals gain a better understanding of how the various dam components behave under different loading conditions and how society's level of risk tolerance changes with time. This manual is a "living document" that will change to reflect evolving national practice. As this manual improves with time, it will provide a stable reference for good dam safety inspection practice as administrators, program priorities, and statutes change. The manual consists of five separate parts:

Part 1 describes ownership responsibilities and roles, risks and hazards of dam failure, and provides a detailed overview of dams in Indiana.

Part 2 presents guidelines for operating and maintaining a dam, including specific instructions on how to prepare a management and maintenance plan and how to respond to emergencies.

Part 3, this part, provides guidance on evaluating dam safety and performing dam inspections. It covers who should perform the inspections and how, and provides guidance on identifying and reporting dam deficiencies and problems.

Part 4 describes guidelines for preparing Emergency Action Plans (EAP) to guide the dam owner during emergency situations. It also covers Emergency Response planning.

Part 5 is a compilation of Dam Safety Fact Sheets that present information on a variety of dam operational issues, such as seepage, slope protection, embankment stability, and spillway design, to name a few.

This manual should not be used in lieu of appropriate dam safety technical courses or training by a dam safety professional in the area of dam inspection. However, it should be used by experienced dam safety professionals as a reference and reminder of the aspects required to make a thorough dam safety inspection and evaluation. It should be stressed, however, that inspections alone do not make a dam safe; timely repairs and maintenance are essential to the safe management and operation of every dam.

The dam owner is responsible for maintaining the dam in a safe condition, and should do whatever is necessary to avoid injuring persons or property. As once stated by a highly respected legal scholar, "It is clear that compliance with a generally accepted industry or professional standard of care, or with government regulations, establishes only the minimal standard of care. Courts may assess a higher standard of care, utilizing the "reasonable person" standard and foreseeability of risk as the criteria. It is fair to say that persons who rely blindly upon a governmental or professional standard of care, pose great danger to others, and present a legal risk to themselves, when they know or reasonably should know that reasonable prudence requires higher care."

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Acknowledgements and Disclaimer

This Manual was developed by Christopher B. Burke Engineering, Ltd. (CBBEL) for the Indiana Department of Natural Resources (IDNR), Division of Water. Principal editors, authors, and support staff within CBBEL included: Siavash E. Beik, P.E. (Project Manager & Technical Editor), Ken Bosar, P.E. (Principal Author), and Jon Stolz, P.E. (Technical Consultant). Principal reviewers and project coordinators at the Division of Water included Kenneth E. Smith, P.E. (Assistant Director) and George Crosby, P.G. (Manager, Dam and Levee Safety Section).

A four-member peer review team provided technical review and advice during the preparation of the manual. The team members included Charles Rucker P.G., Robert Biel, P.E., Thomas Hugenberg, P.E., and John Pfeifer, P.E., all former Army Corps of Engineers dam safety professionals.

Much of the material presented in the manual was adapted from various publications developed by Federal and State agencies for dam inspection, operation, and maintenance. In many cases, pertinent text and illustrations were directly utilized within the manual with permission. A complete list of these publications is provided in the Appendices under References. The photographs were primarily obtained from IDNR and CBBEL files for Indiana dams; some photographs were obtained from public sources. The following is a list of agencies whose publications were extensively used in the preparation of this handbook:

Indiana Department of Natural Resources
Association of State Dam Safety Officials
U.S. Army Corps of Engineers
U.S. Department of Agriculture Natural Resources Conservation Service
U.S. Department of the Interior, Bureau of Reclamation
Wisconsin Department of Natural Resources
Ohio Department of Natural Resources
Colorado Division of Water Resources
Pennsylvania Department of Environmental Protection

Special recognition is given to the Federal Emergency Management Agency (FEMA) who provided funding to the IDNR for the development of this manual. Special recognition is also given to the Association of State Dam Safety Officials (ASDSO) for their leadership in developing effective dam safety programs and policies for the furtherance of dam safety. Their diligence in assisting the U.S. dam safety community was an important factor in the issuance of the FEMA grant.

Use of trade names, brand names, or drawings designating specific products is for reference purposes only and does not constitute an endorsement of products or services by CBBEL, review team members, the State of Indiana, or any of the cooperative agencies/organizations. Information describing possible solutions to problems and concerns, repairs, and emergency actions are intended for guidance only. The dam owner should seek qualified professional help for construction of new dams and extensive remedial measures for existing dams. Site-specific plans, emergency actions, and repair procedures should be developed on a case-by-case basis; CBBEL, review team members, the State of Indiana, any of the cooperative agencies/organizations and references cited assume no responsibility for the manner in which the contents of the Manual are used or interpreted, or the results derived therefrom. Current IDNR regulations pertaining to dams should take precedence to information contained within this Manual.

Indiana Dam Safety Inspection Manual Revisions		
Revision No.	**Date**	**Revisions Made**
0	Aug 28, 2003	First Edition published and placed on IDNR web site.
1	Aug 28, 2007	General grammatical revisions throughout; updated for new dam regulations and policy; added new Part 4, Emergency Preparedness; the original Part 4, Dam Safety Fact Sheets, has been renumbered as Part 5; revised Fact Sheets 1, 9, 11, 14, 17; revised front covers and prefaces; revised Table of Contents.

PART 3 DAM SAFETY INSPECTIONS

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CHAPTER 1.0

INTRODUCTION

1.0 INTRODUCTION

A dam safety inspection program is essential to the long-term stability and safety of a dam and should be part of every dam operation plan. The purpose of the inspection program is to evaluate the structural and operational aspects of the dam, to identify and resolve problems, and to verify that the component parts are functioning properly. An effective inspection program plays an important role in dam ownership and can protect the downstream interests and owner against financial and legal liabilities that can result from dam failures. The inspections should be scheduled and performed on a regular basis. Inspection and maintenance of dams are critical to their long-term performance. However, it should be stressed that inspections alone do not make dams safe; timely repairs and maintenance are essential to the safe operation of every dam.

This part (Part 3) of the Indiana Dam Safety Inspection Manual provides recommended procedures for completing and documenting a dam inspection. The term "inspection," as used in this manual, includes the entire evaluation process, consisting of a project file or data review, a field examination (visual inspection), and report preparation. Depending on current regulatory requirements, the report may need to be submitted to the Indiana Department of Natural Resources (IDNR). The different types of inspections are discussed in Chapter 2.0.

Figure 1-1 Knowledge of concrete and earth structures is required here.

Personnel that perform dam inspections must be knowledgeable in dam design, construction, and operation to effectively evaluate the dam conditions. The inspector should be an experienced, or trained, dam safety professional with expertise in the technical issues encountered at the dam. For instance, the inspector must have knowledge or expertise in structures if the dam has a significant concrete spillway structure, or knowledge or expertise in soils and geotechnical engineering if the dam has an earth embankment (see Figure 1-1). This is especially important if these structures have known problems that need evaluation and repair. The importance of proper inspector training and expertise cannot be overemphasized; the dam owner is not doing himself (or herself) any favors by using unqualified inspectors. A good analogy of this can be found in everybody's personal home life. A responsible homeowner would not hire a landscaper to perform inspections of the heating or plumbing systems in the house, so why would a responsible dam owner hire someone without proper dam expertise to perform an inspection of a dam? The recommended members and expertise of an appropriate inspection team are discussed in Chapter 3.0.

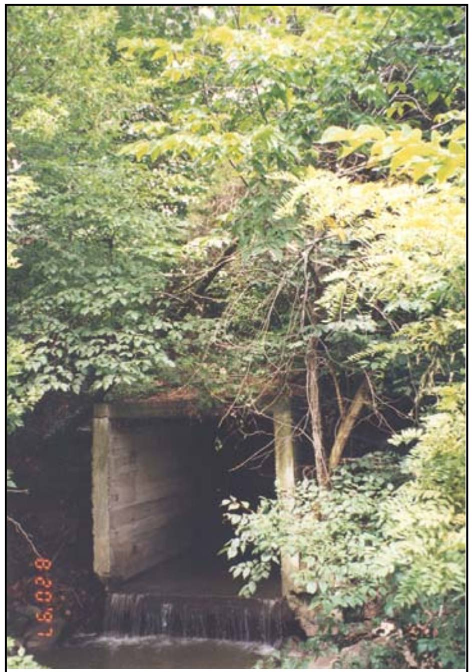


Figure 1-2 Excessive vegetation on this dam embankment makes visual inspection very difficult or impossible.

Inspection personnel must report dam conditions accurately and thoroughly to protect the dam owner's interests and to minimize potential liabilities of both the dam owner and the inspector. Inspectors may be held liable and accountable for dam failures resulting from unreported or understated conditions and problems. It is important for inspectors to document any limitations of their inspection. For example, deficiencies or problems may not be readily detectable at some dams if excessive vegetation is present, if access to certain features is not possible, or if there are problems within the embankment or under a structure that cannot be seen. The inspector is not representing the dam owner's or his/her best interests by overlooking problems at a dam to minimize owner costs or regulatory exposure. Therefore, it is very important that all inspectors develop an unbiased approach to inspections and provide a complete and accurate reporting of existing conditions. If an inspector changes the safety rating of the dam or one of its components from prior ratings, substantive documentation should be provided to support the change. Chapter 4.0 provides details on inspection procedures and documentation.

The Indiana Department of Natural Resources (IDNR) currently classifies dams into one of three categories of hazard classification. A hazard classification is a rating (e.g., low, significant, or high hazard) that is representative of the probable loss of life and property damage downstream from a dam based on the best available information and visual observation of the dam, and/or an identification of the area downstream that would be inundated. The following definitions of hazard classification currently apply to dams in Indiana:

(1) **High hazard dam**: a structure the failure of which may cause the loss of life and serious damage to homes, industrial and commercial buildings, public utilities, major highways, or railroads.

(2) **Significant hazard dam**: a structure the failure of which may damage isolated homes and highways, or cause the temporary interruption of public utility services.

(3) **Low hazard dam**: a structure the failure of which may damage farm buildings, agricultural land, or local roads.

This manual provides guidance for performing safety inspections for all three classes of dams. Dam owners should refer to current IDNR regulations to determine the specific inspection, reporting, and inspector training requirements for their dams. This manual is intended to provide a guide and reference to all individuals performing and reporting dam safety inspections. Chapters 5 through 8 provide a quick reference to be used in assessing observed conditions, their probable cause and possible consequences, and remedial actions that may solve the observed problems or deficiencies. The dam owner or inspector can use the results of inspections to help identify any changes in previously noted conditions that may indicate a safety concern. Quick corrective action to conditions requiring attention will promote the safety and extend the useful life of the dam while possibly preventing costly future repairs (see Figure 1-3).

Figure 1-3 Dam breach failures cause significant downstream damage.

CHAPTER 2.0

TYPES OF INSPECTIONS

2.0 TYPES OF INSPECTIONS

2.1 OVERVIEW

The primary purpose of the dam safety inspection program is to enhance the safety of dams and appurtenant structures for the protection of downstream life and property. Dam safety inspections are made to ensure proper operation and maintenance; to identify unsafe conditions and determine why they exist; to recommend remedial measures that will make the structure safe when necessary; and to insure that the structure meets the minimum agency requirements. Remedial measures may include repairs, redesign, strengthening or reconstruction of the embankment or spillways, modification of operations, storage restrictions, and size reductions. Removal or controlled breaching of a dam so that the water cannot be impounded is also a remedial measure that is normally undertaken only as a last resort.

Four different types of dam safety inspections should be performed for all dams, regardless of their safety hazard classification:

(1) Formal technical inspections
(2) Maintenance inspections
(3) Informal inspections
(4) Special inspections

The frequency of each type of inspection should depend on the hazard classification of the dam, the condition of the dam, and current IDNR regulations.

Table 2-1
Inspection Recommendations

(1)	**Formal Technical Inspection:** Performed initially for all dams and on a regular basis (2 to 5 yrs) thereafter, depending on hazard classification and current IDNR regulations.
(2)	**Maintenance Inspections:** Performed on a regular basis (annual) for all dams; formal technical inspections may be conducted in place of maintenance inspections.
(3)	**Informal Inspections:** Performed on an impromptu, non-scheduled basis whenever the opportunity arises, or as part of a dam monitoring program.
(4)	**Special Inspections:** Performed after the occurrence of unusual or extreme events and emergencies, or as a follow-up to specific concerns.

Every inspection should consist of three to five components, depending on the type of inspection. All inspections should include the first three of following components, while formal technical inspections should also include the last two components:

(1) File review
(2) Visual inspection (field examination)
(3) Report preparation
(4) Owner education
(5) Report submittal (to IDNR)

It should be noted that the visual inspection is just one component of the dam inspection process, and that a dam safety inspection refers to the entire inspection process including the five components described above.

The dam safety inspection program for every dam should begin with an initial, formal technical inspection. First, an evaluation of the background, design, construction, and performance history of the dam is conducted using available files and data. Second, a thorough visual inspection of the entire facility is made to assess and document current conditions. Then, the stability and soundness of the dam are assessed with conclusions and recommendations for repairs or improvements. Additional field, laboratory, and analytical studies may be required if adequate information is not available. The findings, conclusions, and recommendations should be documented in an inspection report, as discussed in Part 3, Chapter 4. All dams may require additional formal technical inspections on a regular basis for as long as the dam exists, depending on hazard classification and current IDNR regulations. The amount of background information needed, the frequency of the inspections, and the reporting procedures are dependent on the hazard classification, the size and type of dam, and current IDNR regulations. For example, high hazard dams which pose a significant risk to downstream property will require more detailed background information and more frequent and rigorous inspections than a low hazard dam with a small reservoir. The level of inspection effort should be commensurate with the potential for damage to downstream areas.

After the initial, formal technical inspection and any required remedial measures have been completed, dam safety inspections should continue to be performed to monitor and detect any unfavorable changes that might develop in the condition of the dam that would adversely affect safety. Subsequent inspections by the same personnel may not require as detailed a review of the background, design, construction, and performance history of the dam as would be required if a new inspector is utilized. However, the inspection program should continue to address the same basic issues that were addressed in the initial formal technical inspection. The continuing dam safety inspections include additional formal technical inspections for high hazard dams, and maintenance, informal, and special inspections for all dams.

A maintenance inspection is a preventive measure designed to identify problems and to develop solutions to prevent further degradation of the dam. Maintenance inspections generally involve reviewing previous inspection reports, performing a visual inspection, and completing a report form. Maintenance inspections are usually performed by the dam tender, maintenance staff, or the dam owner.

In the case of an informal inspection, the evaluation process typically consists of review of previous file data such as reports, photographs, or monitoring data, visual inspection, and completion of a report form or inspection brief. An informal inspection can be conducted at any time, and may include only

Table 2-2
Inspection Reporting Recommendations

(1) Formal Technical Inspection
- Comprehensive Inspection Report
- Suggested Dam Inspection Report
- Photographic Documentation
- Submittal to IDNR for high hazard dams

(2) Maintenance Inspection
- Suggested Dam Inspection Report Optional
- Inspection Brief
- Photographic Documentation
- Project Files

(3) Informal Inspection
- Suggested Dam Inspection Report Optional
- Inspection Brief
- Photographic Documentation Optional
- Project Files

(4) Special Inspection
- Suggested Dam Inspection Report Optional

portions of the dam or its appurtenant structures. Informal inspections are usually conducted by project personnel or dam owners as they operate the dam to monitor known problem areas, or to provide an update on site conditions between maintenance and formal technical inspections.

Special inspections should be performed when potentially dangerous events occur (an extreme flood or seismic event, for example), when the upstream or downstream watershed conditions change (new development, for example), when newly developed, more realistic methods of analysis become available, or as a follow-up to a formal technical or maintenance inspection to deal with a specific issue.

A complete inspection report, the Suggested Dam Inspection Report, or inspection brief should be prepared every time an inspection is performed. A complete report should be prepared for formal technical inspections; an inspection report form or inspection brief may be used for all other types of inspections. The inspection report, form, or brief should document the observations made in the field, present any instrumentation or other performance data trends since the last report, present conclusions on the dam's apparent adequacy, and present any necessary recommendations. The Suggested Dam Inspection Report was developed by IDNR staff and is included in Part 3, Appendix C. The inspection brief is an informal report that consists of a log entry in a book or on a sheet of paper denoting observed conditions, with conclusions, recommendations, or other notes as may be deemed appropriate. If, at any time, the inspector notices any adverse trends, he/she should communicate them immediately to the owner of the dam. Dam owners should refer to current IDNR regulations to determine agency reporting requirements for their dams.

The overall dam safety inspection program is a continuing process of evaluating a dam's performance based on review and analysis of performance records and field observations. A dam safety inspection performed on a regular basis is one of the most economical means a dam owner can use to assure the safety and long life of a dam and its immediate environment. The visual inspection, a component of all types of inspections, is a straightforward procedure that can be performed by any properly trained person to make a reasonably accurate assessment of a dam's condition. The visual inspection component involves careful examination of the surface and all parts of the structure, including its adjacent environment. The equipment required is not expensive, and the visual inspection component usually can be completed in less than one day. The entire inspection process will usually take longer to complete than one day, depending on the type of inspection and the complexity of the dam.

A dam, even though previously found safe by analysis and demonstrated performance, cannot be considered safe forever. Continued vigilance, visually and analytically, is essential. The integrity of the dam must be reevaluated whenever the embankment or discharge structures are damaged, and when upstream or downstream watershed conditions are significantly altered.

2.2 FORMAL TECHNICAL INSPECTIONS

A formal technical inspection of a dam is the most comprehensive inspection that will be performed. It typically consists of five components:

(1) **File review** (or compilation of an information database if it is the first formal technical inspection, or if files do not exist or are inadequate);
(2) **Visual inspection,** or field examination of the dam and its appurtenant works;
(3) **Preparation of a detailed report**;
(4) **Education and training** of the dam owner on the results of the dam inspection and other issues relating to dam safety, including potential dam failure modes. The owner should be made part of the inspection process so that he/she "buys" into the results and is committed taking recommended actions; and,
(5) **Submittal of the report to IDNR**, if so required under current IDNR regulations.

This subchapter describes the requirements for conducting a formal technical inspection. Subsequent chapters describe the actual inspection process in more detail.

The formal technical inspection should begin with a thorough review of the project files and information database, including records of site conditions, project design, dam construction and performance, maintenance records, and previous inspection reports. If the files are incomplete or non-existent, the inspector or dam owner should gather the needed information, or compile a new information database that becomes a permanent part of the owner's project files.

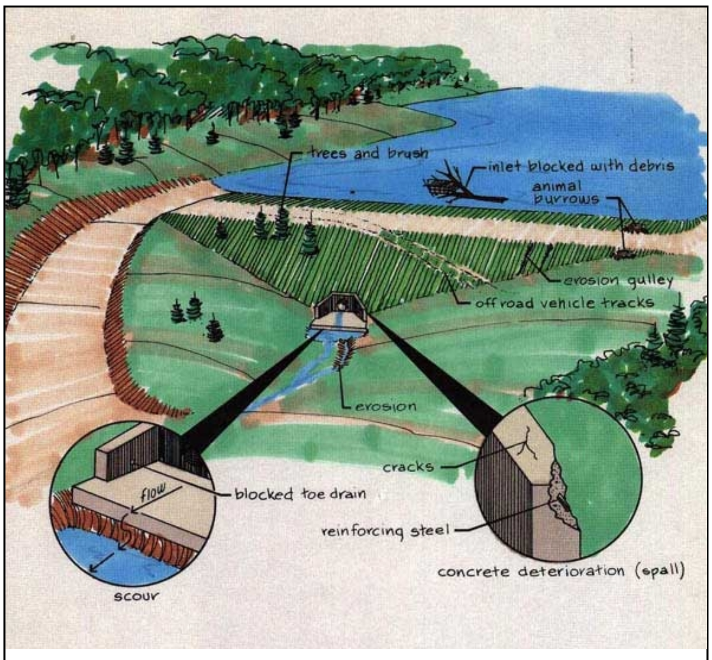


Figure 2-1 Sketch of typical dam features requiring visual inspection.

A formal technical inspection should begin with a review of the hydrologic/hydraulic calculations and geotechnical data to determine if the structures meet current accepted design criteria and practices. If these calculations have not been performed, the inspector should make an estimate of the adequacy of the spillway and embankment stability based on the best available information, followed by recommendations for a hydrologic and hydraulic analysis of the watershed and the dam, and a geotechnical evaluation of the embankment and foundation. It is important that the calculations include overtopping and spillway capacity estimates, slope stability analyses, and embankment seepage analyses. Obviously, if the same inspector performs the dam inspections all the time, he/she will not have to review the hydrologic/hydraulic calculations and geotechnical data every time an inspection is performed.

A visual inspection, or field examination of the dam, its appurtenant works, and the surrounding areas is conducted after the file review and information database is completed. The visual inspections are made to evaluate the safety and integrity of the dam and appurtenant structures in all aspects. Underwater examinations should be performed as needed. Access routes to the dam site and to the individual operating stations should be examined for general suitability, for reliability during periods of adverse weather, and for access during periods of high water or emergencies. A review of the Emergency Action Plan or Emergency Response Procedures should be performed if one has been prepared.

After reviewing all applicable file data and completing the field inspection, conclusions should be made regarding needed monitoring, or remedial measures for repairing, strengthening, altering, or restricting operations. Necessary monitoring and/or remedial measures and their timing should then be recommended. Recommendations should also be made for conducting additional site investigations and engineering analyses, if they are necessary. Chapters 3 through 8 of Part 3 provide additional details on how to prepare for and conduct the visual inspection.

In some cases, sufficient information might not be available in the files or from what can be observed on the ground to provide a solid information base, or a basis for knowing that the dam, its appurtenant works, or the foundations are adequate as they currently exist. In other cases, dam plans and design information may not be available or may not have been prepared before the dam was constructed. In such instances, the inspector should recommend specific investigations that might be necessary to obtain the data, including surveys, geologic mapping, drilling and sampling, laboratory testing, installation of instrumentation, hydrologic studies, geotechnical, and other engineering analyses, especially if the dam's integrity is in question. The recommendations for investigations should be included in the inspection report that is completed following the visual inspection.

A detailed inspection report should be prepared after the visual inspection is performed to document the background information, design, construction and operational issues, as well as the field examination, with conclusions and recommendations. The report should also include pertinent photographs, a completed Suggested Dam Inspection Report, and applicable supporting data. The report should be placed in the owner's project files and submitted to IDNR if required under current IDNR regulations. Chapter 4 of Part 3 describes recommended procedures for documenting and reporting dam safety inspections; Appendix E of Part 3 contains a recommended sample outline of an inspection report.

Formal technical inspections should be the initial inspection for all dams, regardless of hazard classification. After that, formal technical inspections should be performed on high hazard dams every two years, unless otherwise required by current IDNR regulations. Formal technical inspections are not normally performed on a routine basis on low and significant hazard dams unless changing conditions warrant them.

Formal technical inspections typically should be made by a team of one or more professional engineers, geologists, or qualified technicians, accompanied by the dam owner or his representative. Composition of the group is determined by the type of dam and its appurtenant works, and the condition of the dam. The required qualifications of personnel carrying out formal technical inspections are described in Chapter 3. The inspectors must be familiar with the design and construction of dams and qualified to make assessments of structure safety.

Figure 2-2 These inspectors are checking freeboard with a level and stadia rod.

In summary, a formal technical inspection should include the following sequence of work elements:

1. Existing data are collected, reviewed, and compiled in an information database (as discussed in Chapter 3.0). If a dam has instrumentation, the data and analyses of the data should also be collected and reviewed. If an information database is already compiled in a project file, the first step consists of a file review.

2. Using the existing data, the inspector assesses the embankment, spillway, and outlet adequacy and performance. The embankment must be stable under all operating conditions and the spillway and outlet must be capable of safely passing the design flood. The absence or insufficiency of information essential to this part of the inspection (such as foundation characteristics, materials engineering properties, hydrological data, hydraulic analysis, and site seismicity) is identified and actions required to obtain the information are recommended.

3. A visual inspection (or field examination) is then performed to determine the present operational status of the dam, to identify existing or developing dangerous conditions, and to identify the risk to the downstream areas. (Field examination techniques are described in Chapters 4 through 8.) An inspection checklist is an excellent tool to guide the inspector during the field examination. Photographic documentation should cover all components of the dam, including components that are in good condition as well as components that are deteriorating or damaged. Photography of potential downstream hazard areas should also be obtained.

4. The need for additional information should be identified and recommended in the

inspection report. If required, supplemental data should be acquired by exploratory drilling, laboratory testing, reference to published hydrological data, estimation, and special studies.

5. Using the available information, analyses, supporting calculations, and field findings, the inspector prepares a list of conclusions and recommendations.

6. The observations made during the field inspection, the analytical findings, conclusions, and recommendations are documented in a comprehensive inspection report that may include appendices for special studies, laboratory and field-testing, revised flood estimates, photographs and other supporting data. The Suggested Dam Inspection Report contained in Appendix C and the Inspection Checklist contained in Appendix B should be completed and included in the report. If the dam safety ratings on the Suggested Dam Inspection Report change from the previous ratings, the inspector must provide documentation to support the revised ratings.

7. After or during the preparation of the inspection report, the inspector should discuss the results of the inspection with the dam owner or his/her representative to educate him/her on the findings. It is important that the owner is fully aware of the findings and recommendations, particularly if deficiencies exist, and repairs or further evaluations are required. The inspector should encourage the owner to perform all recommended repairs, evaluations, monitoring, maintenance, etc. within a time period that is appropriate for the required action.

8. The formal technical inspection report may need to be submitted to IDNR for high hazard dams, and for other dams if required by current regulations. This step also includes any report revisions that may be required by IDNR. A copy of the report should be placed in the dam owner's project file.

9. Finally, the inspector should summarize and document the dam's deficiencies on the National Performance of Dams Program (NPDP) website at Stanford University. The IDNR should be contacted for additional information concerning the NPDP.

Chapter 3, Part 3 contains recommendations for a complete information database that should be assembled during the formal technical inspection if not already available.

2.3 MAINTENANCE INSPECTIONS

Maintenance inspections are performed to gather information on the current condition of the dam and its appurtenant works. This information is then used to establish needed repairs and repair schedules, and to assess the safety and operational adequacy of the dam. Maintenance inspections are also performed to evaluate previous repairs.

The purpose of maintenance inspections is to keep the dam and its appurtenant structures in good operating condition and to maintain a safe structure. As such, these inspections will minimize long-term ownership and liability costs, and will extend the life the dam. Maintenance inspections should be performed more frequently than formal technical inspections in order to detect at an early stage any developments that may be detrimental to the dam. These inspections involve assessing operational capability as well as structural stability to detect any problems and correct them before the conditions worsen. The field examinations should be made by the personnel assigned responsibility for monitoring the safety of the dam. If the dam or appurtenant works have instrumentation, the individual responsible for monitoring should analyze measurements as they are received and include an evaluation of that data. The Suggested Dam Inspection Report or an inspection brief should be prepared following the field visit (the Suggested Dam Inspection Report is recommended).

Maintenance inspections should include the following four components at a minimum:

(1) **File review** (of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as may be required);
(2) **Visual inspection** (field examination of the dam and its appurtenant works);
(3) **Preparation of a report** (Suggested Dam Inspection Report or inspection brief, with applicable documentation and photographs. The report should be filed in the
dam owner's project files); and,
(4) **Education and training** (if someone other than the owner is performing the inspection).

Maintenance inspections begin with a review of past inspection reports and a cursory review of the complete project file if necessary, paying particular attention to potential trouble spots. The inspector should then perform a visual inspection, or field examination of all physical features and any adjacent endangering conditions. The field examination is a comprehensive search for evidence of deterioration of materials, developing weaknesses, unsafe hydraulic and structural behavior, growth of excessive vegetation, presence of rodents, and soil erosion problems. An inspection checklist is a valuable tool that can be used during maintenance inspections. The field examination should include photographic documentation of all the components of the dam, including components that are in good condition as well as components that are deteriorating or damaged.

Figure 2-3 Maintenance inspection of spillway outlet.

Maintenance inspections should be performed at regular intervals, normally at least once every year, although in special cases more frequent inspections might be called for. Formal technical inspections may be performed in place of maintenance inspections, and the field examination procedures are generally the same for both. For example, if the subject dam has a high hazard classification and requires formal technical inspections periodically, an additional maintenance inspection is probably not required during the years that the formal technical inspection is conducted. In this example, the maintenance inspections would be performed in the years that the formal technical inspections are not conducted. For low and significant hazard dams, formal technical inspections are not routinely conducted after the initial formal technical inspection, therefore the maintenance inspections are the primary component in the dam operation plan. Adjustments can be made in the inspection frequency where unusual or special circumstances warrant. Successive inspections may be made in different months of the year in order to benefit from extremes in reservoir stages and differences in seasonal climatic effects.

The dam owner or maintenance personnel familiar with the project typically conducts the maintenance inspections. The dam safety professionals involved in the formal technical inspections may accompany the inspector, if requested. The inspectors are guided by their familiarity with the complete history of the dam. Their observations, evaluations, and recommendations should be documented on the Suggested Dam Inspection Report or an inspection brief and placed in the owner's project file. Field examination techniques appropriate for maintenance inspections are discussed in Chapters 4 through 8, and a sample checklist for field examinations is contained in Appendix B. The field examination procedures for maintenance inspections are generally the same as those employed during formal technical inspections.

2.4 INFORMAL INSPECTIONS

The third type of inspection, an informal inspection, is a continuing effort by on-site personnel (dam owners, dam operators, and maintenance personnel) performed during the course of their normal duties. Informal inspections will provide a continuous surveillance of the dam and are critical to the proper operation and maintenance of the dam. They consist of frequent observations of the general appearance and functioning of the dam and appurtenant structures. Normally, personnel who are not professional engineers or geologists will make informal inspections; they could be dam owners, operators, maintenance crews, or other individuals whose duties place them near the dam at regular intervals. These personnel are the "first line of defense" in assuring safe dam conditions, and it is their responsibility to be genuinely familiar with all aspects of the dam. Their vigilance in observing the structure, walking the dam, checking the operating equipment, and noting changes in conditions may prevent serious

Figure 2-4 Photographic documentation of embankment slide.

mishaps or dam failures.
Informal inspections are very important and should be performed at every available opportunity. These inspections may only cover one or two dam components as the occasion presents itself, or they may cover the entire dam and its appurtenant structures. The informal inspections are generally not as inclusive as formal technical and maintenance inspections, but should always include at least the following three components:

(1) **File (or data) review** (of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as required);
(2) **Visual inspection** (field examination of the dam, its appurtenant works, or selected features and components); and,
(3) **Preparation of a report** (Suggested Dam Inspection Report or inspection brief, with applicable documentation. The report should be filed in the dam owner's project files).

An inspection report form may or may not be completed; an inspection brief (short note in a logbook or on a sheet of paper) may be recorded and placed in the project file instead. Photographic documentation may or may not be included in the inspection, depending on the type(s) of problems found. Informal inspections are usually conducted to monitor known problem areas, or to provide an update on site conditions between maintenance and formal technical inspections.

2.5 SPECIAL INSPECTIONS

Special inspections may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. Special inspections are not regularly scheduled activities, but are usually made before or immediately after the dam or appurtenant works have been subjected to unusual events or conditions, such as an unusually high pool level, rainstorm, or a significant earthquake. A special inspection may also be performed during an emergency, such as an imminent dam breach, to evaluate specific areas or concerns. They are also made when the ongoing surveillance program identifies a condition or a trend that appears to warrant special evaluation. Special inspections should focus on those dam components that are affected by the unusual event, and should include at least three components: (1) review of applicable files or data, (2) visual inspection, and (3) report preparation. An inspection report form may or may not be completed, depending on the specific situation. The findings may be recorded in a log book or on a sheet of paper (inspection brief) that is then placed in the project files.

More detailed site investigations may be required (such as drilling, surveys, or seepage flow estimates) if the special inspection reveals deteriorating dam conditions. Photographic documentation is usually included as part of the inspection if damage to dam components has occurred.

performance of their dam. Part 1 discusses geologic conditions that could impact dam operation. Figure 2-5 shows maximum recorded 24-hour precipitation events in the United States through 1988 (these values are not PMP values used in design). It shows actual rainfall events that have occurred, and provides an indication of the potential for extreme events. Figure 2-6 shows seismic contours in the Indiana area that represent horizontal acceleration from a seismic event with a 90% probability of not being exceeded in 250 years (typical design values). In general, areas that have acceleration values greater than 10 (i.e., horizontal acceleration values greater than 0.10 times the acceleration due to gravity) should always include a seismic stability analysis of the embankment.

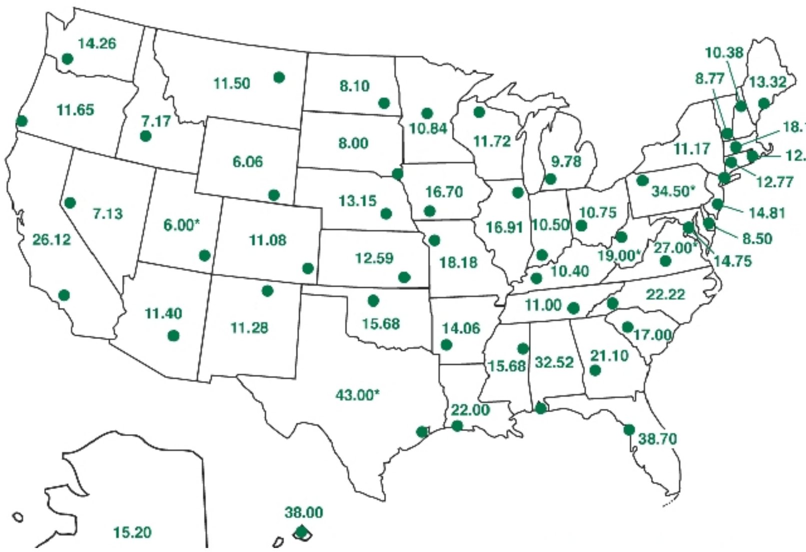


Figure 2-5 Record maximum 24-hour precipitation (in.) through 1998. Source: National Climatic Data Center/ National Oceanic and Atmospheric Administration (NOAA)

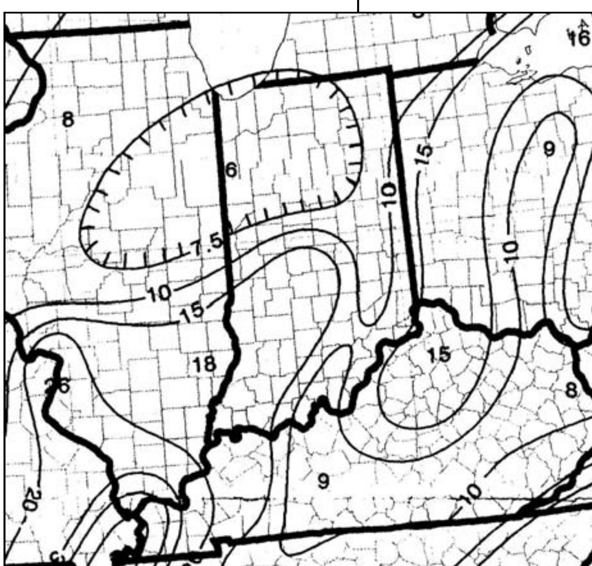


Figure 2-6 USGS seismic contour map, expressed as a percentage of gravity.

Source: Department of the Interior, U.S. Geological Survey

CHAPTER 3.0

PREPARING FOR THE INSPECTION

3.0 PREPARING FOR THE INSPECTION

3.1 INSPECTION TEAM

The required expertise of the inspector or inspection team depends on the type of inspection being performed, the type of dam, and the site conditions. The inspection personnel should be familiar with dam design, the causes of dam failures, and the telltale signs which identify problems or potential concerns. Following the visual inspection, the team members should compare their individual assessments of observed conditions and compile a single composite report.

Table 3-1
Recommended Inspection Team

Formal Technical Inspection

Lead Inspector – registered professional engineer
Assistant Inspector(s) – other professionals as needed based on type of dam and appurtenant works
Dam Owner or representative

Maintenance Inspection

Dam Maintenance Personnel - may be accompanied by a qualified dam safety professional

Informal Inspection

Dam Owner or Maintenance Personnel

Special Inspection

Dam Owner or Maintenance Personnel -should be accompanied by engineer or other professional

Dam inspectors are responsible for the safety of life and property, so they need to recognize when their expertise is inadequate. The Association of State Dam Safety Officials (http://www.damsafety.org/) and the United States Department of the Interior, Bureau of Reclamation (http://www.usbr.gov/dsis/) are two organizations that provide specific training and information that can benefit dam safety inspectors. The Bureau of Reclamation offers an excellent workshop entitled "Seminar on Safety Evaluation of Existing Dams" that provides specific inspection training for engineers, technicians, maintenance personnel, and administrators responsible for dams.

Inspection teams for a formal technical inspection should include a qualified dam safety professional, experienced in dams, as the lead inspector. Necessary team size and member expertise will vary depending upon the type of dam, and the condition of the dam or types of problems that may be present. A formal technical inspection of a dam and its appurtenances requires study, investigation, and analyses of many diverse, individual subjects and conditions, together with evaluations of their interrelationships. Accordingly, this kind of inspection requires skilled specialists with expertise that is pertinent to the dam conditions, and individuals with the broadest possible experience in all phases of dam design and construction engineering for overall review. Inspecting personnel may include individuals who are civil engineers, geotechnical engineers, hydrologists, geologists, structural engineers, engineering technicians, dam operators or tenders, and other specialists, depending on the components of the dam to be inspected. The lead inspector may perform the visual inspection alone if he/she has a broad-based, educational and technical experience with dams and if the dam does not have complex features or severe problems. On larger, complex dams it is likely that no one individual will have all the necessary expertise that is required, and a team inspection will be needed. Larger organizations may be fortunate enough to have staff that includes mechanical engineers, hydrologists, electrical engineers, geotechnical engineers, and other specialists available to evaluate specific features of a dam. Inspecting personnel, regardless of their field of expertise, need to have knowledge in the design, analysis, construction, and operation of dams. The dam owner or his representative should always be present during a formal technical inspection to learn as much as possible about the dam and potential problems.

A maintenance inspection is typically performed by the person(s) assigned responsibility for the operation or maintenance of the dam and its appurtenant works. This person is often referred to as the dam operator or dam tender. The person assigned this responsibility should be familiar with the dam and should possess sufficient knowledge to make accurate assessment of the dam's condition. An engineer or other qualified dam safety professional may accompany the dam operator or tender during a maintenance inspection, but generally does not.

The dam owner, dam operator, or dam tender typically performs informal inspections and special inspections. Again, an engineer or other qualified dam safety professional may be required to assist in a special inspection depending on the specific situation.

The dam inspector(s) should be thorough and organized. In order to readily identify trends, it is necessary to maintain records of performance in an orderly way. Where instrumentation and seepage measurements are available, the inspector should evaluate these records at regular intervals and in a form that makes them easily interpreted. Likewise, observations made during field examinations should be recorded and maintained in the project file in such a way that trends can be visualized readily. Specific recommendations for recording and maintaining data and information appear in other chapters of this manual. If the inspector is unable to interpret or evaluate observed conditions, he/she should seek the advice of a more qualified expert.

There may be times when specialists must apply scientific and engineering knowledge and experience to a wide range of tasks during a dam inspection. These tasks may include interpretation of the geologic structure of dam sites, appraising the engineering properties of the foundation and embankment, predicting and analyzing seepage, calculating and analyzing stresses and stability of embankments and appurtenant structures, evaluating the runoff from watersheds, estimating the capacity and flow in spillways and outfalls, evaluating the mechanical and electrical equipment if present, and analyzing instrumentation and other monitoring data. The proper performance of these tasks usually requires qualified individuals with specific expertise. Occasionally there may be a need for the services of a mechanical engineer, an electrical engineer, or a seismologist. The assistance of engineering and geological technicians, surveyors, and laboratory technicians may also be required. A final coordinated evaluation is then made by a senior individual broadly experienced in all aspects of dam engineering, especially design. This individual is usually a civil engineer, but can also be a soils or geotechnical engineer if the dam is an embankment type.

Highly specialized services may also be required for some dams. These services may include underwater visual inspections, televised conduit inspections, or geophysical investigations. These services are readily available through specialized firms and will usually require advance notification and contractual arrangements. Underwater divers will need to have sufficient details of the project to plan safety and procedural details of the visual inspection. Televised conduit inspection may be required when conduit diameters are small or when direct access is not possible or feasible. Drilling or other geophysical services may be required if additional subsurface information is needed.

The field examination will normally consist of interviews with the owner or operating personnel, a visual inspection of the dam and all appurtenant structures, and observation of the watershed and downstream areas. The manner in which the visual inspection proceeds will depend on the site and type of inspection being made. Performance of the visual inspection will be influenced by weather, ground cover, condition of the structure, personal safety considerations, purpose of the inspection, operational considerations, and even the inspection team's level of experience. The visual inspection team should anticipate these conditions to ensure that proper equipment, clothing, and safety items are on hand. The individual inspector should consider situations when additional personnel will be required to properly conduct the visual inspection and to assure safety. Planning ahead for such contingencies may eliminate the need for a return trip.

3.2 REVIEW OF PROJECT RECORDS

3.2.1 Overview

Proper preparation is important for safety inspections of all types. The project files should be reviewed as the initial step in every dam safety inspection. The extent of the review depends on the type of inspection and how familiar the inspector is with the dam. A complete dam project file should contain four general types of information that constitute the dam information database: (1) background information, (2) design information, (3) construction records, and (4) operation performance records. This information should be reviewed by and be familiar to the inspecting personnel. A checklist of items to be reviewed before the inspection is helpful and will ensure that important documents are not overlooked (see Tables 3-2 and 3-4).

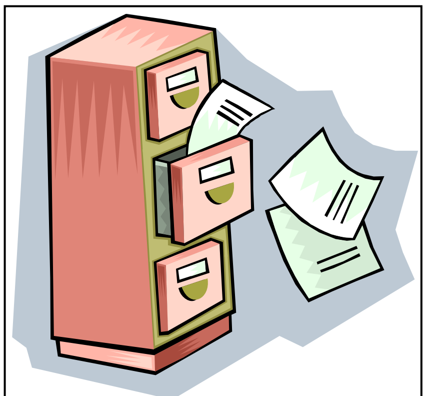


Figure 3-1 Dam owners should maintain complete project files.

A dam project file is essentially a compilation of all information pertinent to a specific dam. A thorough assessment of dam safety cannot be made without ready access to this information. Each organization may have its own guidelines concerning the structure of the dam project safety file; however, it should contain the four general types of information listed above. The goal of the dam project file is to provide ready access to information that can be used to help prepare for conducting a dam safety inspection, evaluate the observations made during a field examination, and have pertinent information available in case of an emergency or serious problem.

Table 3-2
Recommended Information Database for Project Files

(1) Background Information

- Dam owner & responsible parties
- Dam location
- Site topographic mapping
- Surface & subsurface geology
- Exploration techniques employed
- Regional & site seismicity
- Regional Seismic and earthquake history
- Soil surveys and land use
- Photographs
- Emergency Action Plan (if available)

Sources

- Regional & site geologic & seismic reports
- Logs of drill holes & test pits
- Geophysical exploration reports
- Project files & maps
- Materials testing reports
- USGS Quadrangle maps
- County soil maps

(2) Design Information

- Material engineering properties
- Embankment design & materials
- Stability analysis & assumptions
- Structural design criteria
- Drainage area characteristics
- Rainfall & stormwater runoff analysis
- Design flood
- Reservoir flood routing analysis
- Spillway and outlet hydraulic analysis & design
- Mechanical & electrical components
- Hazard potential classification

Sources

- Design reports & calculations
- Technical record of design
- IDNR project files
- Field & laboratory test reports
- Flood hydrology reports
- Hydraulic model reports
- Precipitation and runoff calculations
- Contract plans & specifications
- Dam breach flood routing analysis
- Geotechnical reports

(3) Construction Records

- Construction procedures, methods & control
- Quality control test procedures & results
- Foundation surface characteristics & treatment
- Abutment surface & treatment
- Subsurface treatment & drainage control
- Design-related changes
- Final configuration of dam & foundation
- Extraordinary events during construction

Sources

- Construction specifications
- Daily construction inspection reports
- Construction progress record
- Quality control testing reports
- Foundation acceptance reports
- Project correspondence
- As-constructed drawings & photographs
- Instrumentation installation reports

(4) Operational Performance Records

- Inspection Reports
- Post-construction record floods & seismic activity
- Hydraulic performance of spillway & outlet
- Structural behavior of embankment & foundation
- Water retention behavior of embankment & foundation
- Chronological reservoir stages
- Noteworthy spillway & outlet discharges
- Repairs, alterations or modifications & reasons
- Materials deterioration descriptions
- Layout & performance of surveillance instrumentation
- Original instrumentation design assumptions
- Access route to the dam, spillway & outlet
- Maintenance records
- Operating procedures & records

Sources

- Previous operation & maintenance reports
- Previous inspection reports
- Special inspection reports
- Instrumentation records
- Design operating criteria
- Standard operating procedures & manuals
- Materials testing reports
- Regional & site maps showing access routes
- IDNR project files
- Dam owner's project files

The project records created over the years are essential for a periodic inspection program. These records provide data that form a basis for making engineering evaluations and decisions. They provide project familiarization and orientation to inspection personnel and involved private or public agencies. The project files may also be needed for reference during emergency situations. Knowledgeable personnel familiar with a dam may be unavailable during a crisis, so information in the files may be required to help resolve problems. This source of ready reference is also needed because of personnel turnover and organizational responsibility. Seldom will an individual have been continuously involved in a project since its inception, and personnel assignments change. Collecting this diverse, project record and maintaining it as a continuing record in a permanent file is therefore essential to an effective periodic inspection program and ongoing dam maintenance. When necessary, special exploration and testing, analytical studies, and reevaluation with advanced technology may be performed to obtain necessary information for the project files and inspection efforts.

Project files should be compiled in a systematic format. A standardized, orderly, predetermined arrangement will facilitate the use of the files and accommodate future additions more readily. Generally, the project files will grow with time as new and additional information is added.

The extent of the file review will vary with the type of inspection being performed. For example, if a formal technical inspection will be conducted by a new inspector, the entire project file should be thoroughly reviewed. If an informal inspection will be performed by the dam maintenance personnel, only the previous inspection reports may need to be examined. In any case, the project files should contain a complete information database for the dam in question.

3.2.2 Types of File Review

Generally, there are three types of file review that may be performed as part of a dam safety inspection: (1) preliminary file review, (2) comprehensive file review, and (3) informal file review. The type of review will depend on the type of inspection and the inspector's familiarity with the dam.

Table 3-3
Types of File Review

Preliminary	Identify areas needing further research
Comprehensive	Thorough review of applicable files
Informal	Quick review of specific items

Preliminary File Review

A preliminary file review is an initial review of general information about the dam that will be inspected. Sufficient information is reviewed to:

- Select the appropriate records to review in detail (based on features of the dam to be inspected, geologic areas, etc.)
- Schedule the visual inspection (time of year for the desired operating condition, and the amount of time the inspection will take)

- Select members of the inspection team
- Make arrangements for operation and visual inspection of certain features

Conducting a preliminary file review involves gathering and reviewing general information about the dam to be inspected. The preliminary review gives the inspector an overall picture of the dam, and helps to identify areas which need further research and preparation.

The objectives of the preliminary data review are to:

- Identify the owner of the dam
- Identify the exact location of the dam
- Determine the type of inspection to be performed
- Identify the features to be inspected and features with noted deficiencies
- Identify upstream and downstream conditions
- Determine the timeframe for the visual inspection (time of year and amount of time the inspection will take)
- Determine extent of comprehensive review

Comprehensive File Review

A more comprehensive file review covering all features of the dam should be made after conducting a preliminary review of the file data. The amount of information reviewed and evaluated before the field examination will depend on the type of the inspection and the potential problems that may be present. A review of the entire project file should be performed for formal technical inspections. If the same inspector performs the inspections all the time, he/she may spend less time on some parts of the file, and more time on other parts. If the inspection is the first formal technical inspection for a particular inspector, he/she should review the entire file. Preparation for a maintenance inspection may include a review of applicable portions of the file only, such as operational performance records, construction records of key dam components, and design criteria related to dam spillways and outfalls. If the dam has known problems that are being monitored, that portion of the files that deals with the problem area(s) should be reviewed. Each file review should be tailored to the specific type of inspection and the potential problems that may be encountered.

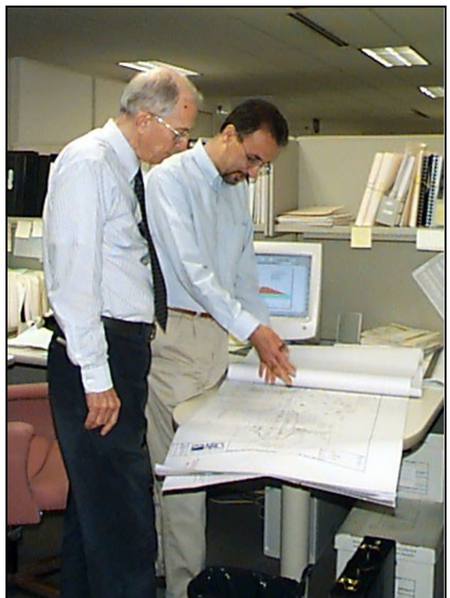


Figure 3-2 Every inspection should begin with a file review.

The objectives of a comprehensive file review are to:

- Reveal potential dam safety deficiencies that may not be visible during the field examination, and identify potential dam failure modes
- Help interpret conditions that may be observed in the field
- Help develop an inspection plan that will ensure a thorough onsite dam safety inspection

Conducting a comprehensive review of available data involves gathering and reviewing all pertinent information about the dam to be inspected. The following general criteria should be identified during the comprehensive data review:

- The type of dam to be inspected and its individual features
- The intended use of the dam and reservoir
- The underlying and surrounding geologic conditions
- Design and construction details pertinent to the safety of the dam
- Operational issues that affect performance
- Presence of instrumentation, and results of data analysis
- Conditions that might, at some point, affect the structural integrity of the dam (e.g., fault zones, lack of drainage features, alkali-aggregate reactive concrete, increasing seepage, etc.)
- Past problems with the performance or operation of the dam or any of its features that need to be addressed during the inspection
- Past problems with the foundation or abutments (during construction or operation) that need to be addressed during the inspection

If a formal technical dam safety inspection is being performed, design and construction details should be compared to current criteria or state-of-the-art to determine whether materials or procedures used at the time the dam was constructed pose a threat to the safety of the dam when compared to current standards.

Informal File Review

An informal file review consists of reviewing select parts of the dam project file in preparation of informal and special inspections. For example, the inspector may only review the previous inspection reports or report forms prior to performing an informal inspection. In some cases, the inspector may review only the project photographs. In most cases, informal reviews are made by personnel thoroughly familiar with the dam who are concerned about a specific dam feature.

3.2.3 Background Information

Background information includes general information and data that define the dam and its environment. This information is generally used to become familiar with the type of dam, its location, and important features or concerns. The following list summarizes the background information that should be included in the project files.

- Dam owner & responsible parties
- Dam location
- Site topographic mapping
- USGS Quadrangle maps
- Surface & subsurface geology
- Site geology reports
- Exploration techniques employed
- Regional & site seismicity
- Regional seismic & earthquake history
- Underground mine maps
- Soil surveys and land use
- Aerial and site photographs
- Correspondence
- Emergency Action Plan
- Expert consultant reviews
- History of site before construction

Figure 3-3 Aerial photograph of a dam and reservoir in Indiana.

Over time, situations or conditions may be created upstream or downstream of a dam that have an effect on the dam and the reservoir. Examples of upstream conditions that could affect the dam are the construction of another dam or a water conveyance system, or the construction of a new housing subdivision. A downstream condition might be development in the floodplain that would change the dam's hazard classification. The inspector should try to identify any new conditions or changes in existing conditions prior to conducting the field examination.

Part 5 of the Indiana Dam Safety Inspection Manual contains a “Fact Sheet” that discusses the geological setting of dams. Included is a physiographic map of Indiana that shows regional geologic conditions and a table that helps define potential conditions which may be present at the project site. This information can be useful for evaluating dam seeps, foundation, or settlement issues and should be checked before the field inspection is performed.

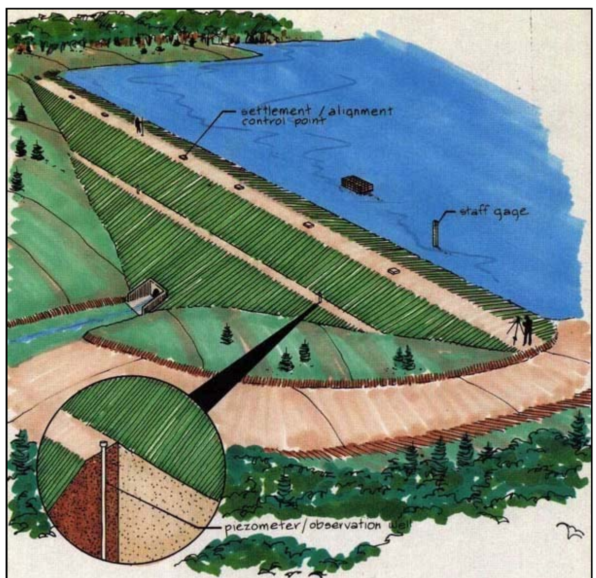


Figure 3-4 A dam sketch showing instrumentation points.

As part of the background research, the inspector should research available seismic history and mapping for the region where the dam is located. Seismic zones that are rather distant form the dam may have an impact on the structure if an earthquake occurs. The New Madrid fault zone in Missouri is capable of producing earthquakes that may affect many parts of Indiana.

3.2.4 Design Information

Design information for dams varies widely in form and detail. Records may be found in the form of simple pencil sketches with brief notations on the dimensions, or as detailed plans and specifications along with complete design and geotechnical reports. The availability of the design documents for review will depend on the completeness of the records kept by the owner, design agency, engineering firm, and regulatory office.

The dam project file should also be carefully reviewed for any documented modifications to the original design. The inspecting personnel must be able to verify structural elevations and dimensions, locations and sizes of appurtenances, and variances from the original design. Design changes, including items which may have been deleted during construction, must also be identified. As-built drawings should be reviewed when available.

Table 3-4
Recommended Design Information in Project File

(1) Design Plans	Location map, site plan, project elements, elevations, materials of construction, sizes of structures, dam hazard classification
(2) As-Built Plans	Actual constructed sizes, locations, modifications, elevations, etc.
(3) Construction Specifications	Materials, general and special procedures, testing procedures and requirements, size and strength requirements
(4) Design Reports	Hydrologic analysis, drainage area characteristics, hydraulic calculations, embankment design, spillway and outlet design, mechanical and electrical component design, stability analysis, seepage studies, settlement analysis, seismic analysis, flood routings, structural design calculations, instrumentation design
(5) Design Calculation Summaries	Supporting calculations with references to engineering methods and standards used in design
(6) Geotechnical/Geologic Reports	Subsurface investigations, boring logs, soil and rock testing results, laboratory investigations, borrow materials and locations
(7) Flood Studies	Upstream and downstream historic flood profiles near dam location, extremes and means of precipitation, historic stream flows and lake and reservoir levels
(8) Technical Journal Articles	Historic design papers
(9) Sedimentation Surveys & Reports	Watershed effects and reservoir availability

Many dams were never formally designed in the first place, so no design or technical information will be available. In the case of an initial formal technical inspection, the review of a design may not be possible until the owner has been contacted or interviewed. The location or even the existence of design documents may not be known until this initial contact is made. Table 3-4 provides a list of design information that may be available in the project file.

Familiarity with the geotechnical aspects of the design can be gained through review of available boring logs, soil laboratory test results, seismic studies, and geophysical data. The extent to which this review is necessary will depend on the location, size, purpose, history of problems, and age of the dam. Since foundation and abutment areas cannot be visually inspected, knowledge of the geology of these areas and how any geologic problems were addressed during construction are very important. Evaluation of existing geotechnical and geologic aspects of a design may be performed best by an experienced geotechnical engineer or engineering geologist. The need for expert evaluation depends upon the purpose of the inspection, the size of the dam and its performance history.

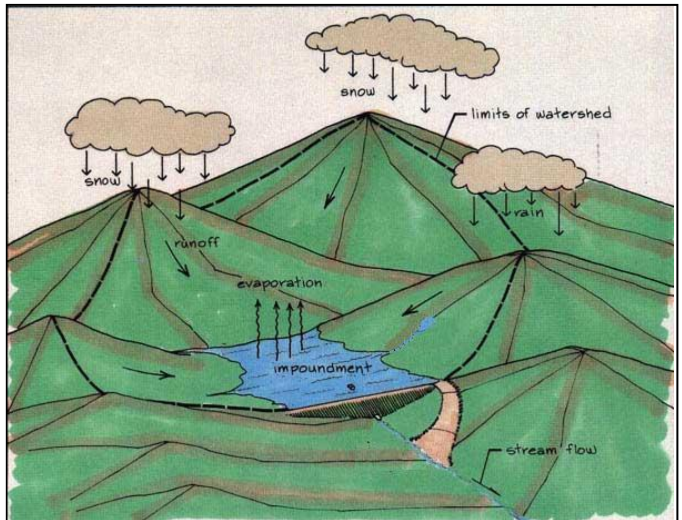


Figure 3-5 Typical hydrologic cycle.

Hydrologic information is used to design the capacities of the spillway and outlet works, and to determine how much freeboard is needed. Rainfall and runoff are important considerations when designing the hydraulic capacity of the dam and spillway structures. Over time, there may be changes to the land upstream that will affect hydrologic conditions, such as land clearing, housing developments, and other land usage. These changes could affect the amount and timing of runoff, the resulting reservoir level, and the amount and rate of spillway discharge. Therefore, during a formal technical inspection, the inspector must look at how the hydrologic design was developed and whether any conditions have changed which could affect the dam design. If the hydrologic information is dated, a hydrologist may have to reevaluate the data and methodology used to determine if changes need to be made to the dam or the spillway based upon current conditions or design standards.

The inspector should also examine downstream conditions to determine whether any changes have occurred that could affect the dam hazard classification or discharge characteristics. Construction of new buildings, houses, or other structures within the potential area of flooding could change a dam's classification from low or significant hazard to high hazard. This can impact the type and frequency of inspections that are required, as well as IDNR reporting requirements, depending on current regulations.

3.2.5 Construction Records

Construction records depict the quantities and types of materials used, variances from design plans and specifications, and any unusual geologic or other conditions encountered. Quality control efforts that were employed during construction may also be available, along with field and laboratory testing results for the dam materials. Remedial actions to correct significant problems which developed during construction, such as removal of unsuitable foundation soils, may have required the preparation of supplemental plans, specifications, and other project documents. Alterations to plans and specifications may be documented in many different forms including inspector's reports, letters, diaries, meeting minutes, special investigation reports, photographs, plan revisions, and specification alternates. Unfortunately, such alterations may or may not appear on as-built drawings. Complete omission of a design item during construction is also not unusual.

Figure 3-6 Construction photograph of spillway and embankment rehab.

Sampling and testing records of the soil used in embankment construction are critical to understanding the stability and seepage potential of embankment dams. This information is often collected during construction and enclosed in the construction documentation report. Embankment soil density and moisture sampling and testing are two of the most commonly obtained construction parameters. Control of these two properties and compaction lift thickness is critical to embankment construction. Soil particle size determinations and soil classification are two more parameters commonly monitored during construction. Complete project files should contain information on these important soil properties.

Figure 3-7 Installation of a riser pipe during winter weather.

Progress and inspector's reports will record the seasons through which construction was performed as well as document weather, construction equipment, material sampling and testing, and site conditions. When performing the inspection, this information can assist in evaluating any newly observed or previously known condition at a dam. For example, temperature extremes and dry or wet conditions, which occurred during construction, may have a direct correlation to dam seepage or settlement problems. Project engineers, technicians, the dam owner, and the contractor may need to be interviewed to obtain information about the construction to fully understand an observed condition. Figure 3-7 shows a dam's riser structure being installed during cold weather conditions. Troubleshooting potential future seepage problems along the discharge pipe may be aided if such photographs are available in the dam owner's project files.

The geotechnical aspects of a design may change during construction due to unforeseen foundation and abutment conditions such as the presence of a weak or fractured rock zone, or an underlying porous soil layer. Unexpected effects of excavations, blasting, and other alterations on the ground water and hillside slope stability may have been documented in the construction records along with the corrective or mitigative actions taken. When available, photographic records provide excellent documentation of construction problems and their resolution.

Construction documents will usually indicate the type of equipment used. For example, these records can help determine the degree of compaction and the rate of construction. The number of passes a soil compactor made for each lift can be used to indicate degree of compaction. The presence or absence of special equipment such as water trucks, discs, or scarifiers could provide clues to the in-place condition of constructed materials. The type of soil compactor used should be described, including the type of machine, size or weight class, and the length of the compactor pad feet. It is equally important to determine the types of equipment used in concrete construction such as transit-mix concrete trucks, on-site batch plants, cranes, conveyors, and pumps. It is important to know the type of equipment used to install discharge conduits.

Foundation and abutment preparation is a critical construction task that should be well documented with written records, maps, and photographs. All vegetative and other organic material should have been removed and replaced with suitable, recompacted soil. Records of key trench excavation, abutment preparation, backfilling, and compactive effort can be helpful with troubleshooting foundation drainage issues.

The preparation of the spillway subgrade, especially spillway conduits, should be documented during construction. The type of bedding used, the compaction efforts, and the method of backfilling conduit trenches can have a significant impact on the prevention of seepage. Methods of conduit placement and joint sealing are also important issues that can help understand subsequent problems that may develop.

Specific techniques or methods of construction that were used may have been documented. Hydraulic fills and mine tailings or coal refuse embankments are examples of dams constructed using special methods. Hydraulic fill dams may be more susceptible to seismic forces. Construction of dams with hydraulic fills, mine tailings, and coal refuse are not recommended and should be avoided. These types of structures can be impaired with both stability and environmental issues.

A critical time in the history of any dam is the first filling of the reservoir. Although construction may be complete by this time, the reservoir filling may be documented in construction records. Observations of seepage, cracks and other conditions which appeared after the dam began impounding water may be included in these records.


Figure 3-8 Loose fill inappropriately added to embankment slope.

Alterations or modifications may occur to a dam at any time after construction is completed. In some cases, an older structure such as a wood crib dam may have been reconstructed by adding earthfill or concrete, completely covering the original dam. Additional soil fill may have been placed on embankment dams to reduce the slopes or to repair defects such as settlement or erosion. Spillways may have been replaced or upgraded if the original structures were deteriorating or damaged. The design and construction records of these subsequent changes, and whether they followed applicable agency requirements, should be reviewed, if available. Dam owners should beware of performing un-designed and un-permitted modifications to their structures. Such modifications can subject the owner to potential legal and liability issues, and could result in regulatory fines, damage payments to downstream property owners, or prison when lives are lost if the dam fails as a result of the modifications. The inspector should note any unapproved modifications in the inspection report or the Suggested Dam Inspection Report.

3.2.6 Operational Performance Records

Instrumentation data will likely be the least available information for most dams. Many smaller dams will not have any instrumentation. The purpose and types of instrumentation that does exist should be familiar to the inspection team. Table 3-5 lists typical instrumentation used to monitor dams. Systems for monitoring the performance of a dam can be very complex or very simple. The more complex systems require experienced personnel to retrieve and evaluate readings and measurements. Even If they do not possess this expertise, inspecting personnel should still be aware of the location, design, and purpose of any monitoring devices to evaluate their physical condition.

All available operation, maintenance, and inspection records maintained by an owner, regulatory agency, or other entity should be reviewed. Operation records should include any previous monitoring data. Records may be reviewed before, during, or after the inspection, depending on availability and the field inspection findings.

Data collected from instrumentation and monitoring systems should be stored in the files and kept indefinitely, unless qualified technical personnel indicate otherwise. Available monitoring records should be checked for location, type of instrumentation, method of data collection, purpose of instrumentation, and type of data collected. Records may apply to instrumentation added to a dam before it was constructed or after it was constructed. Instrumentation installed after construction is usually done to monitor a specific problem which was not apparent during the original design, or which developed after the reservoir filling is complete.

Table 3-5

Type of Dam Instrumentation

Piezometers - Pneumatic - Hydraulic - Diaphragm - Open standpipe	Measure ground-water levels and pore pressures in foundations and embankments
Horizontal & Vertical Movement Devices - Surface monuments - Settlement gages - Extensometers - Inclinometers	Measure horizontal and/or vertical movement in foundations, embankments, and appurtenances
Seismic Instruments	Measurement of earth motion
Weirs, Flow Measuring Devices	Measurement of seepage, water releases
Concrete Structures - Strain/Deflection - Joint/Crack Movement - Stress/Pressure/Uplift - Water Leakage - Plumb Lines and Tilt - Alignment - Seismic Instruments - Temperature	Devices for determining stresses and movements of a concrete structure with respect to allowable tolerances
Pool & tailwater level gages - Staff gages - Pressure gage - Riser markings	Measurement of water levels/elevations

3.2.7 SOURCES OF INFORMATION

The information sources for a specific dam may be in several locations, depending upon the developmental history of the project, previous file maintenance techniques, personnel involved with the dam, and any ownership changes.

Records for dams constructed with the Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service) or IDNR assistance may be found in the active files and archives of those agencies. If design or other engineering services were provided by other Federal agencies such as the Bureau of Reclamation (now the Water and Power Resources Service) or the U.S. Army Corps of Engineers (USACE), records may be located in the archives of those agencies. Engineering firms that have been involved with the dam should have project files concerning the work they performed. IDNR has conducted regulatory dam safety inspections on all dams known to be within the agency jurisdiction. If dams of interest or concern to the NRCS or the U.S. Forest Service are or have been under the jurisdiction of a state agency, data sources may be in their files.

Recent aerial photographs are useful for viewing upstream and downstream conditions and are recommended for use during the dam safety inspections to map or sketch dam features and deficiencies. The Indiana Geological Survey, Google Earth, and Microsoft TerraServer-USA, are good sources of aerial photography.

In some instances, information might be obtained from the files of the contractor who constructed the dam, but it will likely be of limited extent and value. However, the possibility of obtaining photographs should not be overlooked.

Newspaper accounts will sometimes provide helpful information, especially during periods of sensational events such as large floods or earthquakes. While reliable facts and engineering considerations will seldom be obtained from such accounts, useful photographs may have been taken or historical events may have been recorded.

If the dam is noteworthy or unusual, engineering and construction contracting periodicals may have published some dependable data concerning its design and construction. Reliable accounts of dams constructed many years ago will sometimes appear in old engineering periodicals. Journals and technical publications of engineering associations such as the American Society of Civil Engineers and the United States Committee on Large Dams often contain reliable data on dams. However, such data are usually available only for large, notable dams.

Interviews with persons associated with the project during its construction and subsequent operation can sometimes provide answers to specific questions. Such persons may include contractors' representatives, individual workmen, owners, owners' engineers, operation and maintenance personnel, IDNR representatives, and members of the general public. Responses obtained by such interviews must be carefully screened and evaluated,

Table 3-6
Sources of Information

Construction Documentation Records
Design Reports & Calculations
Slides/Photographs/Newspaper Articles/Other Publications
Precipitation Records & Observations
Lake/Reservoir Levels & Observations
Dam Safety Inspection Reports
Operation Reports
Routine Maintenance Records
Routine Equipment & Gate Operations Records
Instrumentation Readings
Dam Repairs & Equipment Rehabilitation Records
Regulatory Agency Reports & Permits
- State (DNR)
- Local Energy Regulatory Commission (FERC)
- Environmental Protection Agency (EPA)
- U S. Army Corps of Engineers (USACE)
- U.S. Bureau of Reclamation (USBR)
- U.S. Department of Agriculture (USDA)
- U.S. Geological Survey (USGS)
- Natural Resources Conservation Service (NRCS)
- National Databases

Sedimentation Surveys
Inspection Reports (Owner, Regulatory Agency, Consultant, Others)
Regional & Site Geologic & Seismic Reports
Logs of Drill Holes & Test Pits
Geophysical Exploration Reports
Project Files & Maps
Materials Testing Reports
USGS Quadrangle Maps
County Soil Maps
Field & Laboratory Test Reports
Contract Plans & Specifications
Geotechnical Reports
Project Correspondence

considering the involvement and background of each person.

The records and files for existing dams vary considerably in completeness, quality, and usefulness. Their existence and character will vary with the age of the facilities, the type of ownership, and the project engineer, if there was one. In many cases, records (especially of design and construction) may be totally nonexistent, fragmentary, or inaccurate. It is important, however, that a diligent search be made for all records, because the information therein may be vital and unavailable from any other source (e.g., treatment of unusual or difficult foundations). Available data relating to the general area around the dam and reservoir should also be reviewed.

3.3 INSPECTION FIELD KIT

A wide range of equipment may be required by the team to satisfactorily perform the safety inspection. The equipment needs depend on many parameters such as weather conditions, type of dam, complexity of design, condition of the dam, instrumentation, and purpose of the inspection. Below is a listing of general equipment, specialized equipment, and safety equipment and protective clothing which may be useful to the inspection team.

Figure 3-9 A typical inspection field kit.

Equipment should be maintained properly and stored securely when not in use. Instruments should be adjusted properly, inspected often, and calibrated regularly. Misplaced or damaged equipment can reduce the effectiveness of or even alter the outcome of the inspection. Personal equipment items include clipboards, field notebooks, pencils, pocket rulers, proper clothing, and pocket knives. Also, a reduced copy of the drawings for the dam being inspected is a convenient means to have design data readily available during the inspection.

General Inspection Equipment

Inspection Checklist - Serves as a reminder to inspect for all important conditions. An example is presented in Appendix B.

General Embankment Sketch - A sketch of a typical dam embankment may be used to denote the location and dimensions of deficiencies on the embankment and abutments of the dam. A ruler may be useful for scaling dimensions on the sketch. A high resolution aerial photograph of the dam is recommended for use during dam inspections (see Appendix D, Part 3).

Notebook And Pencil - It is very important to write down observations at the time they are made. This reduces mistakes and the need to return to the area to refresh the inspector's memory. A clipboard can provide a sturdy writing surface.

Tape Recorder - A small portable tape recorder can be used effectively to make a record of field observations when it is not convenient to make written notes.

Camera - Photographs provide a reliable record of observed field conditions. They can be valuable in comparing past and present configurations. An inexpensive model usually takes pictures good enough for inspection records. Modern digital cameras are excellent for the development of comprehensive photographic records.

Hand Level - This is needed to locate accurately areas of interest and to determine embankment heights and slopes. A **surveying rod** (stadia rod) or other type of measuring rod is a useful aid in determining measurements.

Probe - A probe can provide information on conditions below the surface, such as the depth and softness of a saturated area. Also, by observing moisture brought up on the probe's surface, the inspector can decide whether an area is saturated or simply moist. Probes with a metal tip are preferred. An effective and inexpensive probe can be made by removing the head from a golf club.

Tape Measure - Many descriptions are not accurate enough when estimated or paced. The tape measure provides accurate measurements which allow meaningful comparisons to be made.

Flashlight - The interior of an outlet in a dam can often be inspected adequately without crawling through by using a good flashlight or fluorescent lantern.

Shovel - A long-handled shovel is useful in clearing drain outfalls, removing debris, and locating monitoring points. A short-handled shovel may suffice and is more convenient to carry.

Rock Hammer - Questionable-looking riprap or concrete can be checked for soundness with a rock hammer. Care must be taken not to break through thin spots or cause unnecessary damage.

Bonker - The condition of support material behind concrete or asphalt faced dams cannot be determined by observing the surface or facing. By firmly tapping the surface or the facing material, conditions below can be determined by the sound produced when the material is tapped. Facing material fully supported by fill material produces a "click" or "bink" sound, while facing material that is over a void or hole in the facing produces a "clonk" or "bonk" sound. The bonker can be made of 1 ¼ inch hard wood dowel with a metal tip firmly affixed to the tapping end. A rubber shoe like those on some furniture legs is recommended for the other end to allow the bonker to be used as a walking aid on steep, slippery slopes.

Binoculars - These are useful for inspecting limited access areas especially on concrete dams. They are also useful for inspecting risers and trash racks that are not accessible from the dam embankment.

Bucket and Timer - These are used to make approximate measurements of seepage or leakage flows. Establishing the time it takes the seepage flow to fill the bucket enables the inspector to calculate the number of gallons per minute. Various container sizes may be required, depending on the flow rates. More accurate measurements can be made with a flow meter when the discharges are relatively large.

Stakes and Flagging Tape - These are used to mark areas requiring future attention and to stake the limits of existing conditions, such as cracks and wet areas, to allow future comparison.

Knife or Machete - These tools can be useful for clearing weeds and brush, and for scraping rocks or soil.

First-Aid Kit - A basic first-aid kit should be part of every dam inspection kit in case of injury. At a minimum, it should include assorted bandages, anti-septic medicine, pain relief tablets, sunburn lotion, ice packs, a splint, sterilized gauze, scissors, tweezers, and sterilized tape.

Specialized Equipment

Video Camera - A video camera, preferably digital, can be used to record the entire site; this may be particularly helpful for concrete dams or spillways where access is difficult. A high-power magnification can be very useful when videotaping concrete dams. Most video cameras are also equipped with sound and date recorders.

Inclinometer - An inclinometer is used to make quick measurements of embankment slopes.

Flow Meter - This instrument is used to measure flow velocity and quantity. The flow must be relatively large; small seeps can not be measured with a flow meter.

TV Monitor - A TV monitor is used to view and record conditions inside pipes and conduits that are inspected with a video camera mounted on a remote control vehicle.

Two-way Radios - These are useful for communications when more than one inspector is present on relatively large sites.

Confined Space Access Equipment - This includes equipment for personnel access to vertical risers, discharge conduits, etc, where emergency retrieval may be necessary. This includes such things as ropes, harnesses, and ladders. It also includes portable gas meters for testing confined spaces for harmful gases that may be present. These may be required when entering discharge structures under the ground.

Boats - A boat may be required for access to areas on the reservoir, including shorelines and spillways.

Piezometer Gage or Water Level Indicator - Used to measure depth to water in piezometer or water wells.

Pocket PC's and Laptop Computers - These portable computers are a convenient tool for making field inspections cost effective and efficient. The computers must have software that is designed for dam inspections, and must be compatible with other office equipment so that the information can be readily transferred to the inspection report. Pocket PC's are often referred to as "PDA's."

Global Positioning Sensor (GPS) – Handheld GPS units are recommended for use in mapping deficiencies found during inspections, such as seeps, slides, and cracks. GPS units can be used to monitor progression of deficiencies over a period of time if they are accurate enough. GPS units access GPS satellites to determine the users position. The best units can be used to determine both spatial coordinates and ground surface elevation.

Safety Equipment and Protective Clothing

Hard Hat - A hard hat is recommended for inspecting large outlets or when working in construction areas.

Rope - Can be used when inspecting steep slopes or conduits. A rope can also be used when inspecting areas along the shoreline. Generally another person should be present to assist with the use of a rope.

Bug Repellent - Biting bugs can gravely reduce the efficiency and effectiveness of the inspector and sour his disposition. Ticks and mosquitoes can cause skin irritations and severe health problems in some instances.

Snake Bite Kit - In areas where rattlesnakes or copperheads might be present, a snake bite kit should be included in the first-aid kit; protective leg guards are also available.

Watertight Boots - These are often required when inspecting various areas of the dam site where standing water is present. Waist-high waders are useful for riser inspection.

Steel-toed Shoes - Steel-toed shoes should be used when there is a danger of debris falling on the inspector's feet.

Sturdy Hiking Boots - Hiking boots may help prevent slipping and falling when traversing slopes and wet areas. Good ankle support can aid in preventing injury to ankles.

Life Jacket - A life jacket is a good idea for inspecting areas where there is a danger of falling into the water, especially along the shoreline of a deep reservoir, or a reservoir with steep upstream slopes. They are a necessity if the inspector is using a boat.

Cellular Telephone - A cell phone can come in handy in emergencies or when additional information is needed from the office or the owner's office.

Safety Glasses - May be required in some cases for eye protection.

Gloves - May be useful if stakes are being installed, or if riprap and deteriorated concrete are being investigated.

Orange Vest or Coat - If inspections are performed during hunting seasons, bright colored clothing is a good preventative measure to avoid shooting accidents.

3.4 INSPECTION SCHEDULING

Inspection scheduling is dependent on numerous factors, such as who will be present, where the dam is located, the type of inspection, the time of year, and the condition of the dam. All individuals who are to attend the inspection must be notified of the date, time, and location. The scheduled time and date will need to accommodate everyone's personal schedule. Coordination with state and federal agencies, local government officials, industrial owner representatives, engineering consultants, and individual private owners may be necessary. Representatives of divisions or sections internal or companion to the regulatory dam safety agency may need to be included. If an interview with the owner, operator, or other individual is to be conducted separately, the meeting location and time should be established appropriately. In setting the time for the inspection, time zone changes, and travel times for all parties should be considered. The amount of vegetation on the embankment and the level of water in the reservoir or spillway can also have a direct impact on inspection scheduling.

The dam owner or operating personnel should be notified in advance if they will be asked to assist in the inspection. For example, areas may need to be dewatered or equipment may need to be operated. Drawdown equipment should be checked at least once per year to make sure it is working properly. Also, arrangements for gate or door keys, transportation, and special equipment should be made ahead of the inspection.

There are two principal criteria for determining the general time frame for a dam safety inspection: the time of year (or season) in which the inspection will take place, and the time it will take to perform the actual inspection. After the general time frame is established, the specific day and time of day can be scheduled.

If many or all of the features of the dam will be inspected, the time of year or season in which the inspection will take place can be important. The inspection may need to be performed when the reservoir is at its lowest point or after a large release of water so that those features or areas of the dam that are normally under water are exposed.

Table 3-7
Things to Consider when Scheduling Inspections

Weather and seasonal conditions
Amount of vegetation present
Dewatering outlets, spillways, and stilling basins
Special equipment needs and availability
Planned aerial photography
Reservoir level
Recent seismic or precipitation events
Owner/operator requests
Agency-mandated inspections
Type of inspections
Underwater inspections
Inspection team members
Availability of inspector(s)
Travel distance to dam
Inspection safety concerns
Existing litigation

Also, removal from service and inspection of some features may be possible during periods of limited operational requirements. If the inspection requires that certain features be tested or inspected as close to full design load as possible (i.e., maximum reservoir elevation), the inspection may need to occur when the dam is at its normal yearly maximum elevation. This may also allow the inspector to observe equipment as it operates under maximum design loading conditions.

Inspector safety and convenience may play an important role when scheduling a visual inspection. While a dam should be accessible any time of the year for inspections, if the embankment area is heavily vegetated it may be best to inspect the dam when the vegetation is dormant (late fall, winter, or early spring). This may make it easier to locate settlement, cracks, or animal burrows. Overgrown vegetation is inappropriate for any dam and should not be present to hinder inspection; however, in reality there are dams that do have inappropriate vegetative growth. If snakes are present at the site, the inspection may be scheduled for those periods when the snakes are inactive (cool weather months). Insect presence (bees, ticks) may also be a determining factor for scheduling an inspection. Inspecting a dam when it is raining, snowing, or extremely cold or hot could pose specific health and safety concerns for some inspectors.

Existing litigation issues may hinder dam inspection if the dam files are “frozen” or if site visits are prohibited under court order. In some cases, visitors are not permitted at the dam site unless officers of the court accompany the inspector.

Consideration should also be given to the time it will take to perform the inspection. A comprehensive visual inspection could take a full day or more than one day and additional travel arrangements may be necessary. In some cases, it may be desirable to return to view an identified problem area under different weather conditions or other circumstances. Return visits and inspections extending more than one day may not require the presence of all parties, who should be so advised. After it has been determined what features of the dam will be inspected as well as the general scope of the project, review of the records of past inspections may reveal how long the inspection will take. Experience will also aid in judging the length of inspections.

In summary, the amount of time the dam safety visual inspection will take is dependent on the following factors:

- The size and complexity of upstream and downstream areas to be visited
- The type of inspection being conducted (e.g., an initial, formal technical dam safety inspection will take longer than a special inspection)
- The number and complexity of appurtenances to be inspected
- Whether the inspection requires operation of drawdown or spillway structures
- The size of the structure. If the dam is a very long embankment dam, it will take considerable time to walk and inspect all the features (to inspect the upstream slope, downstream slope, and crest). If it is a large concrete dam, it may have numerous galleries.
- The size of the inspection team
- The condition of the dam and its appurtenant works. Dams in generally poor condition may require significantly more time to observe and document the conditions.
- Dams inspected during inclement weather generally will require more time.
- Underwater inspections and conduit TV recordings will take considerable time.
- Whether the reservoir will be inspected in addition to the dam, and what method of inspection will be used.
- The location of the dam. Dams that are located a considerable distance from the inspector's office will require significant travel time.
- Unknown, unexpected conditions

3.5 INSPECTOR SAFETY

The inspector should be aware of and plan for potentially hazardous site conditions that may be commonly found at dams. Inspectors should use appropriate safety gear and clothing when needed, and should always use extreme caution when performing visual inspections of dam spillways, embankments, riprap areas, and shorelines. Potentially dangerous areas and hazards include steep or wet embankment slopes, spillways with high sidewalls or flowing water, spillway conduits, confined spaces, riprap areas with large stones, outlet structures containing water, shorelines with riprap and deep water, concrete embankments, sinkholes, outlet banks, and high grass or bushes. Some of the dangers presented by these features include slipping, falling, drowning, tripping, lack of oxygen or presence of noxious gases, stepping in holes, snakes, and bee stings.

Low head dams constructed across streams and rivers also present a safety hazard in the area immediately downstream of the dam. The whirlpools, hydraulic jumps, and eddies created from the discharging water are extremely dangerous to boaters and swimmers, and there have been many drowning accidents that have occurred in such areas. It can be very difficult or impossible for swimmers and boats to escape from this area, especially during periods of increased flow following precipitation events. For this reason, these dams are often referred to as "drowning machines."

Some dams are located in remote areas where illegal activities may be conducted by people living in the area (such as drug labs or drug cultivation). In this case, intruders, such as dam inspectors, may not be welcome and may be in danger of physical harm by the people performing the illegal activities.

If a site has known safety hazards, it is essential that the visual inspection be conducted by more than one individual. The use of two inspectors is always a good idea because of the potential to slip and fall into the water or down the embankment.

3.6 CONTACTING THE OWNER

The dam owner or operating personnel should be notified in advance if they will be asked to assist in the inspection. Interviews with the owner, operator, owner's engineer, project personnel, and others may be conducted before, during, or after the inspection. A formalized interview and records review form is an excellent way to ensure that pertinent questions and information are not overlooked. Previously unavailable files, operation and maintenance records, emergency action plans, and other records can be reviewed. If the interviews are conducted before the inspection, the team can determine if there are any specific areas that should be examined. Questions about the dam can be clarified, possibly adding better understanding of the dam's design, construction, and past performance. The inspection team can evaluate the adequacy of the owner's or operator's records and then advise the owner or operator on ways to improve the documentation and project files.

Review of records will provide the inspection team an opportunity to discuss normal operation procedures with the owner or operator. Although information may have been available about previous dam operation, current procedures may have changed. Special operations such as a reservoir drawdown or water releases may be revealed. The inspection team may also check their visual observations against the owner's records after the inspection.

The dam owner or his representative should be present during the field examination. If they are not present, the inspector should contact the dam owner or his representative after the inspection is performed to discuss the results. The inspector (or inspection team) should brief the owner or operator on the preliminary findings, clarify any questions, make suggestions about record keeping, updating the Emergency Action Plan (if one exists), operations, or monitoring, and explain any follow-up activities that may be required.

The inspector should also educate the owner on all issues relevant to dam safety, including how the deficiencies that are observed could progress and lead to a potential failure situation. Potential dam failure modes should be discussed so that the owner understands how his/her dam could fail and under what conditions. The inspector should also provide any training tips that may help the dam owner spot and correct deficiencies, as well as how the deficiencies develop (i.e., what causes them to occur).

CHAPTER 4.0

INSPECTION PROCEDURE

4.0 INSPECTION PROCEDURE

4.1 DEVELOPING AN INSPECTION PROCEDURE

The purpose of a visual inspection is to identify deficiencies that potentially affect the safety and operation of the dam. An inspector should develop a methodical procedure for inspecting a dam to ensure that all features and areas are examined and to optimize the amount of time spent in the field. First, the previous inspection reports should be reviewed to note any areas that will require special attention. However, the inspection should not be limited to the information on previous inspection reports. Second, inspection equipment should be assembled, necessary file reviews should be performed, interviews with pertinent people should be made, and site access should be arranged. Then, a plan of approach should be prepared for the visual inspection of the dam. Finally, the inspection should be documented as described in Part 3. Additional provisions may be required, including such things as mowing the grass or clearing brush on the embankment, shutting off outlet flows, pumping down low areas with standing water, or opening gates and drawdown valves. Concrete dams may require special consideration and access provisions.

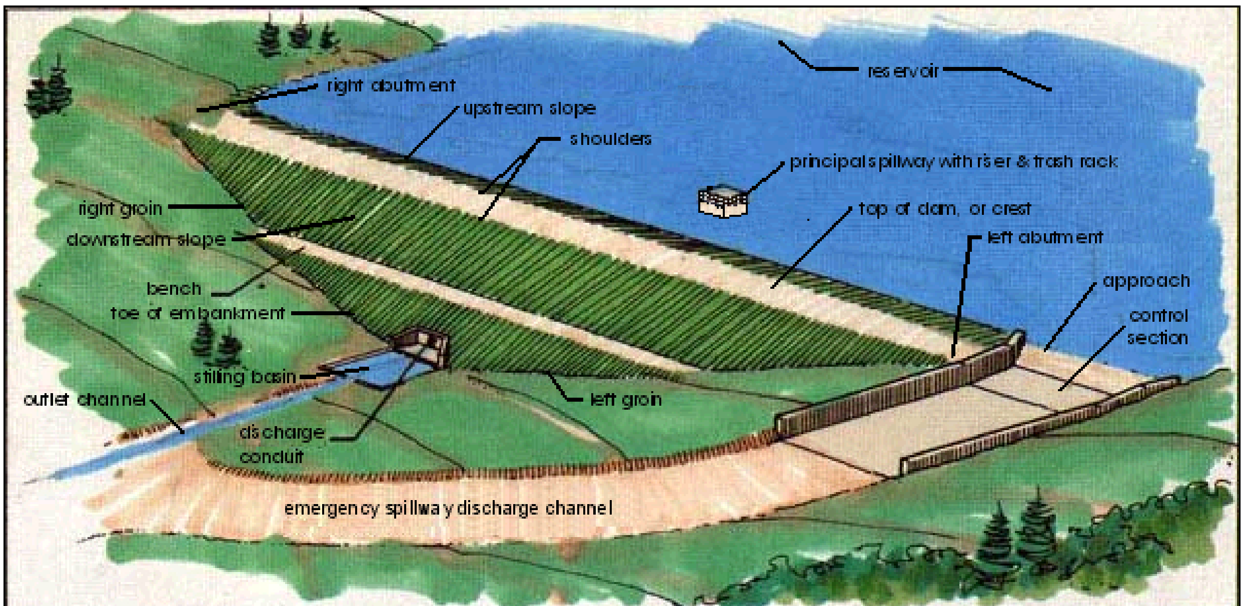


Figure 4-1 Sketch of typical dam features (the left and right sides of the embankment are referenced by looking downstream).

Figure 4-1 shows typical features that require inspection and are common on embankment dams. Dam features and descriptions should be referenced "looking downstream." For example, with the inspector standing on the embankment crest and looking downstream, the abutment on his/her right is the right abutment; the abutment on his/her left is the left abutment. Concrete dams may have similar features except they do not have an earthen embankment. Other features that are common at dams but are not shown include rock toe drains with piping, cutoff trenches, and riprap groin areas.

It is helpful to prepare an inspection route in advance to assure that every part of the dam will be observed. An inspector can take many different approaches to inspecting a dam, but the selected method should be methodical to ensure that all features are covered and to make the best use of his/her time in the field. A recommended sequence to assist with a visual inspection is presented below. This sequence generally starts at the top of the dam and proceeds downward. Sometimes it may be more effective to inspect the easiest, or most readily accessible areas first, or those areas of known problems. However, no matter where the inspector is located on the dam or spillway, he/she should stop periodically and look around for 360 degrees to observe other features from that vantage point.

(1) **Crest** - Walk across the crest from abutment to abutment, observing both upstream and downstream slopes while inspecting the crest surface.

(2) **Upstream & downstream slopes** - Walk across the slopes in a parallel or zigzag pattern along the embankment from abutment to abutment, starting with the upstream slope. (This may not be possible on concrete dams.) Particular attention should be paid to the downstream slope below the elevation of the reservoir.

(3) **Embankment-abutment contacts** - Walk the entire length of the embankment-abutment contacts (groin) on both sides of the dam, on both the upstream and downstream embankments (do in conjunction with slope inspections).

(4) **Principal Spillway** - Observe all accessible features of the principal spillway and its outlet. Inspect the inlet while performing the upstream slope inspection. Inspect the outlet during or after the downstream slope inspection is completed.

(5) **Emergency Spillway** - Walk along the entire length of the emergency spillway in a back and forth manner.

(6) **Abutments** - Traverse abutments in a practical manner so as to gain a general feel for the conditions, which exist along the valley sidewalls.

(7) **Outlet Works and Downstream channel** - Carefully inspect outlet works and reservoir drains that may be present. Travel the route of the stream below the dam to identify residences and property which can be affected by dam failure.

(8) **General Areas** - Drive or walk along the perimeter of the reservoir and other upstream areas. Carefully inspect all other appurtenant works that may be present at the dam.

Additional details of inspection procedures for selected features are provided below. Following Chapters present more detail on specific dam features and problem areas, along with possible solutions to correct observed deficient conditions.

4.1.1 Inspecting Embankment Slopes

The general technique for inspecting the slopes of an embankment dam is to walk over the slopes as many times as is necessary in order to see the entire surface area clearly. From a given point on the slope, the inspector can usually see small details for a distance of 10 to 20 feet in each direction, depending on the roughness of the surface, vegetation, or other surface conditions. Therefore, to ensure that the entire surface of the dam has been covered, the inspector must repeatedly walk back and forth across the slope until he/she has clearly seen the entire area, giving greater scrutiny to the downstream slope below the pool elevation. The following patterns can be used for walking across the slope.

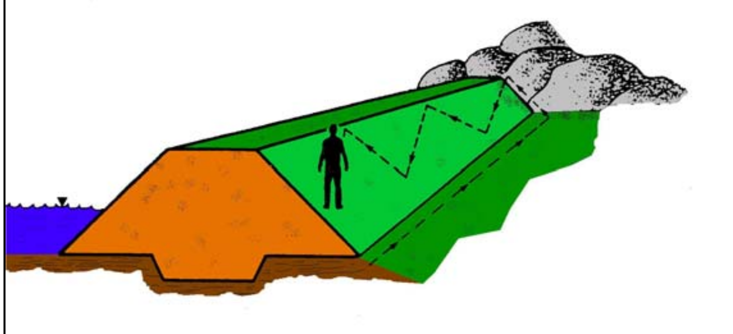


Figure 4-2 Inspecting an embankment using a zigzag approach.

Zigzag (See Figure 4-2)

A zigzag path is one recommended approach for ensuring that the inspector has completely covered the slopes and crest. It is preferable to use a zigzag path on small areas or slopes that are not too steep.

Parallel (See Figure 4-3)

A second approach is to make a series of passes parallel to the crest of the dam, moving down the slope. It is preferable to use parallel passes on larger slopes or on slopes that are very steep, since this method is less arduous.

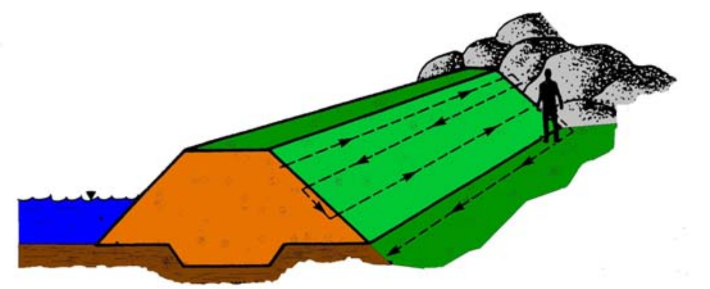


Figure 4-3 Inspecting an embankment using a parallel approach.

Both of these techniques are acceptable methods for inspecting the dam slopes and crest. Whichever technique is used, the goal is to be able to see the entire area clearly. Reaching this goal may require that you walk the area several different times for dams with high embankments. At regular intervals while walking the slope, the inspector should stop and look around for 360 degrees to check the alignment of the surface. The inspector should double check the procedure to make sure that no areas or deficiencies have been overlooked. By stopping and looking around in this fashion, the inspector should be able to view the slope from different perspectives. Seeing the slope from different perspectives sometimes reveals a deficiency that might otherwise be undetected.

In addition, viewing the slope from a distance may also reveal anomalies such as distortions of the embankment surfaces and subtle changes in vegetation. Often these types of observations are not apparent when viewing them close-up. Finally, viewing the downstream slope and toe area of the dam from a distance at a time of day when the angle of the sun is low can reveal wet areas. The wet areas become more visible due to the reflection created by the sun.

4.1.2 Inspecting Embankment Groins

The inspector should thoroughly inspect the areas where the abutments contact the embankment by walking these areas. These areas are called the groins; it's where the embankment toe intersects the existing ground surface. The groins are susceptible to surface runoff erosion, and seepage often develops along the downstream groins. The best approach to inspecting these areas is quite simple: the inspector should walk down the left (or right) groin, and then walk up the groin on the other side of the dam. The same approach is used for both upstream and downstream groins. The inspector should also check the toe of the embankment when examining the groin areas.

4.1.3 Inspecting the Crest

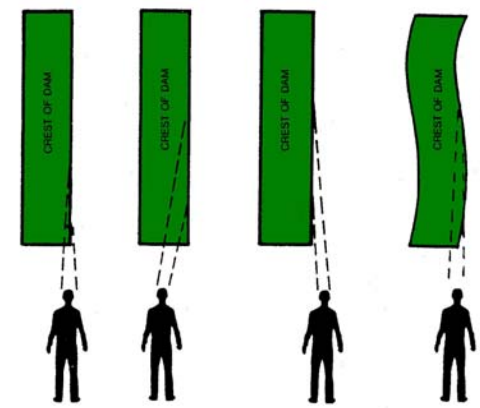


Figure 4-4 Sighting along an embankment crest.

Inspecting the crest is similar to inspecting the slopes. The inspector can use either a zigzag pattern or a parallel pattern to inspect the crest. The inspector should walk the crest as many times as necessary to cover the entire area. To ensure that no deficiencies go undetected, thorough coverage is required. The important thing is to look at every square foot of the surface area. Another helpful technique is to view the crest from different perspectives. Some deficiencies can be spotted close-up, while other deficiencies can be observed only from a distance. The sketches on the left side of Figure 4-4 show sighting along a straight embankment, while the sketches on the right side of the figure shows sighting of a bowed embankment.

Figure 4-5 Crest problems may be easily seen by sighting along a straight line on the crest.

When checking the alignment of the crest and any berms on the upstream and downstream slopes, the inspector can use a simple sighting technique to identify misalignments and other problems. The inspector should center his/her eyes along the line being viewed and move from side to side to view the line from several angles. The use of binoculars or a telephoto lens can help the inspector observe irregularities since distances are foreshortened and distortions become more apparent. The use of a reference line can also be of great assistance in sighting. Reference lines can be existing features such as guardrails, a row of posts, pavement stripes on the roadway running along the top of the dam, parapet walls, and permanent monuments that serve as horizontal or vertical control points along the surface of the dam. However, when using man-made reference lines, the inspector must check to make sure that the features have not been displaced by other causes, such as vehicles, lawn mowers, vandalism, tractors, etc. When sighting along the crest, the inspector needs to view the chosen reference line from a number of different perspectives. First sight on a direct line; then move to either side. This sighting technique is also useful for detecting a change in the uniformity of the slope. The contact between the reservoir waterline and the upstream slope should parallel the alignment of the dam axis. In other words, the reservoir waterline should be a straight line if the dam has a straight axis. To check the alignment of the waterline, the inspector should stand at one end of the dam and sight along the waterline. Misalignment of the waterline may indicate a change in the uniformity of the slope.

4.1.4 Inspecting Spillways, Outlets, and General Areas


Figure 4-6 Spillway access may make inspection difficult.

Spillways and outlets may be difficult to access, so the best approach is to walk closely along or in the structure, depending on access, and view all surface and internal areas, if possible. If conduits are large enough and appear safe, the inspector should be able to walk into the structure with a flashlight and view the inside areas. If the structure is in the water away from the shoreline or embankment, the inspector may need to use a pair of binoculars or a camera/video camera with a telephoto lens. Pictures or videos can be taken and reviewed carefully from a safe location. Boats or underwater divers may need to be employed to observe some features. Shorelines and upstream areas may be accessed on foot or by vehicle. Other appurtenant works should be closely inspected, item-by-item, from as close a distance as possible. Gates may need to be closed to make the inspection possible. Some structures may not be readily accessible and will require binoculars or video equipment to observe current conditions. Closed conduits may contain noxious gases or may lack sufficient oxygen, making them dangerous for inspectors. The inspector should always check questionable areas


Figure 4-7 Spillway with large flow.

for the presence of gases or the lack of oxygen before entering them.

4.1.5 Inspecting Concrete Dams

Figure 4-8 Dam with significant concrete spillway structures.

Although concrete dams comprise less than 1% of the total number of dams within the state, they are potentially more dangerous than embankment dams. Some embankment dams have significant concrete structures (composite dams), making inspection of them similar to inspection of both concrete and embankment dams. Basic procedures for inspection of a concrete dam are similar to those of embankment dams, except that the crest and faces of the dam may be very difficult to access. Therefore, inspector access and safety should be a primary concern on concrete dams. The faces of concrete dams are often near vertical, and the upstream slope is usually damp and slippery. Access to the downstream face, toe area, and abutments may be difficult and require special safety equipment such as safety ropes, or a boatswain's chair. Close inspection of the upstream face may also require a boatswain's chair or a boat. Without this equipment, inspection of all surfaces of the dam and abutments may not be possible. Another method of inspection that may be used consists of videotaping the dam faces from a safe point using a high power magnification on the camera. The inspector can zoom in on the surface areas and get a close up view and recording of the dam. The inspector should start filming at a discernable point, such as the top or toe of the dam face at the point of contact with the abutment. The inspector should then slowly move the camera across the face of the dam with smooth parallel movements, proceeding up or down the face after a sweep is made across the entire length of dam. Sufficient overlap of adjacent, vertical areas needs to be incorporated in the process to ensure that all areas are covered. This technique can be deployed from a boat or on the ground for the upstream and downstream faces, depending on access. The inspector may have to move along the face if the dam is relatively long. Every square foot of the dam surface can be recorded if the inspector is careful and methodical.

Figure 4-9 Dam requiring extensive concrete inspection.

The inspector should look for common ailments on concrete dams, including structural cracks, foundation or abutment weakness, deterioration due to alkali-aggregate reaction, cracks at construction joints, deterioration due to spalling, and leakage. Construction joints are provided to accommodate volumetric changes, which occur in the structure after concrete placement, and are referred to as "designed" cracks. These joints are so constructed that no bond or reinforcing, except non-bonded waterstops and dowels, extend across the joint. Outlet system inspection should be emphasized during inspection of tall concrete dams. Reading of an established monitoring network should be performed on a regular basis.

The American Concrete Institute (ACI) Report 201.1, “Guide to Making a Condition Survey of Concrete in Service,” may be useful to inspectors if concrete structures are present.

4.2 DOCUMENTING THE INSPECTION

It is important for the dam owner/operator to keep records throughout the entire life of the dam. Accurate records can better illustrate the dynamic nature of the structure and will help pinpoint problems. It is recommended that the dam owner establish a permanent file to retain inspection records, including records of actions taken to correct conditions found in such inspections. Chapter 3.0 contains details on the type and extent of records that should be kept in the project file.

4.2.1 Method of Documentation

The following methods can be used to record a visual dam inspection:

Inspection Checklist – A convenient way of compiling inspection observations is by recording them directly onto an inspection checklist. The checklist should be attached to a clipboard and carried by the dam inspector as he/she traverses the entire structure. An example of a very detailed checklist can be found in Part 3, Appendix B. It is a good idea to complete a checklist for formal technical inspections and dam maintenance inspections. A checklist will not typically be required for informal and special inspections.

Each type of inspection may have its own checklist format, and the particular format used for an inspection may be predetermined by the owner or IDNR. The benefits of using a checklist include: (1) a checklist is easy to follow and comprehensive (if properly prepared); and (2) a checklist allows the inspector to make comments or take photographs in response to a predetermined list of features and conditions at the dam.

The inspection checklist should be included in the dam inspection report, and is required in the report that is submitted to IDNR for high hazard dams.

Field Sketch – A good practice to follow along with filling out the inspection checklist is to draw a field sketch of observed conditions. The field sketch is intended to supplement the information recorded on the inspection checklists; however, it should not be used as a substitute for clear and concise inspection checklists. Problems and their location can be recorded on the field sketch. This record may be prepared for any type of inspection. Appendix D (Part 3) contains a sample field sketch consisting of an aerial photograph of the dam; this type of sketch is highly recommended.

Photographs – Inspection photographs can be vitally important. Over time, photographs serve to provide a pictorial history of the evolving characteristics of a dam. The dam owner/operator often finds them to be great money savers because they can illustrate that some observed conditions (seepage, foundation movement, etc.) have existed for many years and may have reached a state of equilibrium. With this knowledge, quick and economical remedial actions can be developed and implemented. Photographs should be dated on the back (if they are not digital format) and provided with brief descriptions of the locations shown in the pictures. More details regarding the importance of photographs and other visual documentation procedures are provided in Subchapter 4.2.2. Photographs are required in the report that is submitted to IDNR for high hazard dams.

Monitoring Data – It may become necessary to make measurements of various items during the course of a dam inspection. This may include measurements of seepage rates, spillway discharge rates, settlement, upstream and downstream water levels, and for some dams, readings from instruments such as piezometers. It is important that this data also be compiled in a systematic manner and placed in a permanent file.

Inspection Report Form – Current IDNR regulations and Non-rule Policy require the completion and submittal of an Inspection Report Form (shown in Part 3, Appendix C) for formal technical inspections on high hazard dams. A detailed written report incorporating the Inspection Checklist, Inspection Report Form, summary of findings, recommendations, conclusions, photographs, and other supporting data must be prepared for formal technical inspections. The format shown in Appendix C should be followed for all high hazard dam safety inspection reports

Notebooks – The inspector may elect to keep a field notebook that documents all of the observations and findings in addition to a checklist. Notebooks can provide convenient records of dam inspections if they are formatted in a logical manner and are thorough.

Figure 4-10 Pocket PC (PDA).

Tape Recorders – Tape recorders, especially the micro-recorders, can be very convenient when it is difficult to write while the inspector is observing field conditions.

Pocket PC's and Laptop Computers – Pocket PC's (also referred to as "PDA's") and laptop computers are convenient tools for entering field inspection data in reports being prepared in the office. While laptop or notebook computers have traditionally been used for data collection, advances in Pocket PC's make them an excellent choice for the field. Pocket PC's have a variety of peripherals available and can operate for weeks between charging or battery replacement. One of the biggest advantages and potential for Pocket PC's lies in their capabilities for customization. Inspection checklist software has been developed as part of the Dam Safety Program Management Tools (DSPMT). Plug-in software applications are available for a variety of dam specific inspection checklists, including Fill Dams, Concrete Dams, Spillways, Powerhouses, Instrumentation, etc. Using a Standard ACCESS database interface, users can easily configure the Pocket PC-based application to only present the inspection checklists utilized by the user's organization. Inspection checklist reports can be beamed directly to an IR-enabled printer; synchronized with Outlook Notes and edited in Word, or synchronized with the DSPMT Desktop. The Pocket PC's must be synchronized with a desktop system to incorporate the inspection data into a compatible inspection report.

Global Positioning Sensors (GPS) – Handheld GPS units are becoming more popular for use in recording coordinates (location) and sometimes elevation (more expensive units) of physical earth features, such as dam deficiencies, spillway location and extent, and limits of other appurtenant features. They can be particularly useful for monitoring the progression of deficiencies such as seepage areas, cracks, sloughing, and erosion.

Whatever the form of the documentation, the inspector should record his/her observations. These notes should contain information that can be used later to write an inspection report, a letter to the dam owner, an Inspection Report Form, or a memo to the project files. The inspection notes should be clear and specific, leaving absolutely nothing to memory. They should be organized in such a way that they document the present condition of each feature of the dam. In addition, any potential problem or defect that was identified during the records review should be noted and, during the inspection, its current condition should be recorded. The information recorded in written or tape-recorded notes should typically include:

- Inspection team participants
- Climatic conditions, especially rainfall (amounts if known), immediately prior to and at the time of the inspection
- Operating conditions such as reservoir and tailwater elevation, spillway and outlet discharge, etc
- Condition of all inspected features
- Any mechanical or electrical features
- All location, elevation, and other descriptive information
- All quantitative measurements, including instrumentation readings and surveying results (if taken)
- Safety hazards that could pose a threat to the public or project personnel
- Description of changes in the upstream and downstream areas
- Notations on any verbal information gathered, prior to or during the inspection, from operating personnel and other individuals who are not members of the inspection team

Unless the dam owner or regulatory agency has a specific policy on how notes will be taken, the inspector will need to decide whether to use written or tape-recorded methods for recording information during the inspection. Table 4-1 compares some of the advantages and disadvantages of using written and tape-recorded notes. The inspector should not rely solely on the use of tape-recorded notes. If the inspector chooses to record the majority of the inspection notes using a tape recorder, some data should also be recorded in a written format to serve as a backup in case problems are encountered with the tape-recorded notes. The combined use of written and tape-recorded notes will allow the inspector to take advantage of the good points of both methods.

Table 4-1 Comparison of Written Notes and Tape-Recorded Notes

ADVANTAGES	DISADVANTAGES
Written Notes:	**Written Notes:**
● Provide more of a permanent record.	● Takes time to write down information.
● Do not require any special equipment.	● May be difficult to read if handwriting is poor.
● Can combine sketches with written notations.	● Difficult to do when it is raining.
Tape-Recorded Notes:	**Tape-Recorded Notes:**
● Easier to say a lot and, therefore, capture more information.	● Dependent on having equipment that is in good working condition (batteries may fail, inadequate microphone may not pick up all the information, background noise)
● Easier to use when recording information	● Tapes must be transcribed. Transcriber may not be able to decipher garbled information.
● Easier to use when raining, but hard on the recorder	● Tapes could break or be erased.

4.2.2 Visual Inspection Documentation

Visual records should always be made to supplement a visual inspection. This form of recordkeeping visually illustrates any features or phenomena that the inspector observes during a dam safety inspection. The three types of visual records generally used during a dam safety inspection are: (1) photographs, (2) videotapes, and (3) annotated drawings and sketches.

Each of these three types of records can be a very effective means of recording information and should be included as part of the report.

Photographs are an excellent means of note taking, and they provide a permanent record of current conditions for future comparisons. They also provide an essential element to the written inspection report.

Figure 4-11 A picture is invaluable documentation.

It is recommended that the inspector use a 35mm camera or a digital camera (preferable) to take photographs during an inspection. These cameras typically have provisions for zooming in to magnify the features being observed. If a 35mm or digital camera is not available, an instant camera may be substituted. Using an instant camera may be helpful since the inspector can see the quality of the photographs while onsite. Also, instant photographs can be used for any immediate consultations that may be necessary back at your office. Color photographs are preferred to black-and-white prints because the color of certain deficiencies is important inspection information (e.g., changes in the color of concrete or vegetation). It is often hard to describe in words what can be captured in a photograph (see Figure 4-11).

It is helpful to make a written or tape-recorded note of the picture number, what the photograph portrays, where the photograph was taken, and the direction from which the photograph was taken and other reference information (e.g., station, elevation, etc.). Having notes about the photographs taken will help the inspector remember important information about the photographs after they are developed.

The inspector should take a large variety of photographs during each inspection, including both wide-angle shots and close-up shots of features. In addition, it may be helpful to take a series of photographs that later can be taped together to create a panoramic view of the dam and its features.

When choosing the position from which to take photographs, select the camera angle that best illustrates the feature being inspected. Whoever is reading the final inspection report should be able to clearly see and understand what the inspector is trying to illustrate about each feature. The photographs should present an exact, pictorial essay of what the inspector or other team members saw. The pictures should visually recreate the inspection so that the readers feel as if they were actually at the dam site.

There are three camera positions, which are typically used when taking photographs:

(1) A similar position as before: This allows comparison with the latest photographs with earlier ones.
(2) A different angle than before: This allows a different aspect of the feature to be viewed compared to what was photographed previously.
(3) A variety of angles: This allows the feature to be studied from a number of different directions to highlight the different surrounding characteristics.

Careful study of earlier photographs provides an excellent method of reviewing the condition of the soon-to-be-inspected dam. Such careful review of previous pictures is also important so that the inspector can take photographs of the dam features from similar perspectives.

One other factor that should be taken into consideration when choosing camera position is the quality of available light. Poor lighting obviously will result in poor pictures. Choose the camera position so as to make the most of angle and lighting. Also, watch out for shadows that will block out important details or sun in the camera lens. Figure 4-12 shows an example of picture quality when an automatic digital camera shutter speed is controlled by including the trees in the background rather than the sky; the result is a brighter picture. Figure 4-13 shows a photograph of the same scene at about the same time, but with more of the sky included in the background; the result is a shutter speed adjustment based on the sky. A darker picture is the result.


Figure 4-12 Picture with shutter speed controlled by the treeline.

It is always helpful to include recognizable objects in the photographs, providing, whenever possible, references for location and scale. For detail photographs, scale can be indicated by using a familiar object such as a pencil or notebook and placing it next to the object to be photographed. A measuring tape or ruler, if properly placed, can help show the approximate size of such aspects as a joint opening or the width of a crack.

After the photographs are developed, they should be labeled with the photograph number, name of the dam, description of what is being shown in the photograph, and the date the photograph was taken. Also it may be helpful to use paste-on arrows to point to specific features, deficiencies, and conditions.


Figure 4-13 Picture with shutter speed controlled by the skyline.

A video camera, especially with audio recording, is very effective for recording either general or specific coverage of a dam's features. Divers frequently will use a closed circuit television camera during an inspection to make a videotape. The use of closed circuit television cameras provides two benefits: it documents the inspection, and it allows for instructions to be given to the divers. Closed circuit television cameras can also be used to record the conditions inside a conduit, which cannot be accessed by the inspector. It is important to include references for location and scale in the videotape footage using the same techniques that are used for still photographs. Location references can be achieved by beginning with a wide shot of the area to be videotaped and then slowly changing to a close-up shot. Measuring devices or common objects can be used to indicate the dimensions of a feature or deficiency. If a measuring device is used, make sure it is large enough to be seen clearly on the videotape.

There are both advantages and disadvantages to documenting an inspection with videotapes. The quality of a videotape record is often not as good as that of photographs, unless it is a modern digital camera. It is difficult to compare previous photographs or old videotape footage with more recent videotape footage. This difficulty may lessen the inspector's ability to determine what changes have occurred over time. However, the ability to combine audio and visual records is a definite advantage. The audio portion of a videotape can be an excellent means of recording the sounding of concrete structures with a hammer or bonker while photographing the location and visual appearance of the concrete surface. If videotape is used to document a dam safety inspection, the inspector should also take still photographs. Videotape is best used to supplement still photographs.

Drawings and sketches provide graphic representations of a dam feature or condition that is being evaluated during an inspection. Drawings are often helpful forms of note taking because they can document and show the location of a particular deficiency. In general, three types of drawings are useful for inspection documentation:

(1) Sketches can be drawn of major features or of a localized area of interest. It is important to record the precise location (e.g., station, elevation, monolith number, etc.) of the feature being sketched. This information will be needed if an inspection report is prepared.
(2) Existing drawings (e.g., standard sketch of the dam or reduced as-built plan or elevation view of the dam) can be used to make notes about a particular feature or to record surveying notes, measurements, or other information. A circle or an arrow can be used to highlight the features or areas of concern.
(3) Aerial photographs of the dam or appurtenant works are now readily available and can be used to accurately locate specific features.

4.2.3 Writing an Inspection Report

The inspector should first gather all the information that will be used in the report. The notes developed during the initial data review and onsite inspection are two important elements. All other pertinent data and photographs that are gathered, analyzed, or reviewed should also be included.

The inspector should review the inspection notes before leaving the field or shortly thereafter, to make sure that he/she understands the notes while their observations are still fresh. They should also make sure that all noted deficiencies are described fully and documented with photographs, including the precise location and relevant quantitative measurements. Tape-recorded notes should be transcribed and the typed version should be reviewed. Often the transcriber (if other than the inspector) will not be able to understand everything the inspector has said.

The inspector should label the photographs after they have been developed (unless a digital camera is used). Next, compare the written or transcribed notes with the photographs. Comparing the photographs to the notes helps to ensure that the notes are complete and accurate. Photographs may reveal concerns that were overlooked in the notes. It is important for the inspector to label photographs while the information is fresh in his/her mind. If videotaping was employed, it is a good idea to review the film footage at this time.

It may be useful to have other inspection team members review the notes if other people were present at the inspection. The goal is to make sure that the notes are complete before report writing begins.

The next step is to evaluate all the information that has been gathered. The amount and types of information gathered may vary depending on the type of inspection conducted and inspection policies and procedures. After the onsite inspection is completed, the inspector may need to evaluate the information collected during the inspection using the information contained in the project file to fully understand the situation. This evaluation can also be done in the field. The results of this type of evaluation may point to another area of the dam or feature to verify or explain an observed condition. Evaluating the information gathered allows the inspector to put his/her thoughts together and develop tentative conclusions and recommendations. The inspector should think about the significance of findings before writing about them.

The inspector must integrate the findings from the data review with the observations made in the field to evaluate the information collected. Field measurements should be checked against design or as-built plans, if available. Instrument readings taken during the inspection should be checked against previous records. Comparisons should be made between previously reported deficiencies and current conditions. The status of previously recommended follow-up actions should be determined. An evaluation of both previous and current data can help identify trends and can be used to assess the seriousness of any deficiencies observed.

The depth and scope of an inspection report depends on the type of inspection that was performed. For example, an initial formal technical inspection report typically requires a greater level of detail and explanation than a maintenance or informal dam safety inspection report. In addition, an initial formal technical inspection report will be broader in scope since, by definition, it includes a comparison of design and construction data against current criteria. The greatest differences among types of inspection reports are the depth to which project features are described and the extent to which design and construction data are analyzed. The depth of a report's conclusions and recommendations also may vary depending on the type of inspection performed and the extent to which data were reviewed during the inspection. A comprehensive data review will probably enable the inspector to draw conclusions that are more thorough and to make recommendations that are more extensive. Although the depth and scope of inspection reports may differ, a comprehensive description of the conditions observed during the onsite inspection should be included in all reports.

The format of the report is generally dictated by the type of inspection performed (i.e., formal technical, maintenance, informal, special) and will determine how the content of the report is to be organized. The formal technical inspection report will be the most comprehensive, while a special or informal inspection report may be very brief, and may consist of only a letter with attached field notes and photographs. Appendix E in Part 3 contains a sample outline of a detailed inspection report that should be included with formal technical inspections and submitted to IDNR for all high hazard dams.

A formal technical inspection report needs to be a complete written and bound document that includes at least the following components:

(1) A title sheet that includes all of the following information:
- The name of the dam
- The state inventory identification number
- The county and river or stream where the dam is located
- The owner's and operator's names, addresses, and telephone numbers
- The date of inspection
- The name, address, registration number, and signature of the licensed professional engineer who is in charge of the inspection report

(2) An executive summary.
(3) A table of contents.
(4) A background section that includes the history of construction including completion date, ownership, operation and any past modifications, problems, incidents and/or failures on the structure.
(5) A project information section that includes all of the following dam specific information:
- The geologic setting and general site conditions
- The purpose of the dam
- A description of the dam, spillway system, and other principal features, together with pertinent data
- A summary of available design, geotechnical, maintenance, construction, repair, and alteration information
- A reference to past inspection reports
- A map that shows the location of the dam

(6) A field inspection section that includes the following:
- A completed Dam Inspection Report (Suggested Dam Inspection Report)
- A description of the physical condition of all features of the dam and appurtenant structures, including the impoundment level, as they were observed during the field inspection
- A description of the downstream area with special emphasis on existing hazards and changes from previous inspections
- Dated and identified photographs of the dam, its appurtenances, the downstream channel, and all deficiencies cited in the report
- Justification for increasing the overall condition rating and/or increasing the rating of a condition on any components from the previous inspection

(7) A structural stability section that includes a visual assessment of the stability of the dam on the basis of available data, together with the observations of the field

inspection and the results of any calculations performed including a summary description of pertinent available information, such as any of the following:

- Geotechnical design data
- Seismic considerations
- Seepage
- Slope stability analysis
- Previous evaluations

(8) A hydrologic and hydraulic section that includes a visual assessment of the adequacy of the spillway system based on available data, together with the observations of the field inspection and the results of any calculations performed including a summary description of pertinent available information, such as any of the following:

- Hydrologic design data
- Drainage area
- Changes in the watershed
- Floods of record
- Previous evaluations

(9) An operation and maintenance section that includes all of the following:

- An assessment of operating equipment and procedures
- Evaluation of the current maintenance plan
- Recommended changes to operation and maintenance procedures

(10) An emergency preparedness and security section.

(11) An overall evaluation of the structure's condition, spillway capacity, operational adequacy, and structural integrity based on current inspection, past performance history, existing documentation and recent analyses.

(12) A determination of whether deficiencies exist that could lead to the failure of the structure.

(13) Recommendations with a schedule to complete for:

- Maintenance, repairs, and alterations to the structure to eliminate deficiencies, including a recommend schedule for necessary upgrades to the structure
- Further detailed studies or investigations
- An assessment of the adequacy of the current hazard potential classification if appropriate

(14) Appendices that include all of the following:

- Engineering plans of the dam, if available, or sketches of the dam and its principal parts, including a plan view and cross sectional views of pertinent features
- If there have been changes to the dam since the submittal of previous plans or sketches, supplemental plans or sketches that depict the changes shall be included
- If engineering plans or sketches have been submitted in a previous inspection report and if there have been no changes to the dam, it is not necessary to submit duplicate plans or sketches in subsequent reports
- Supporting documentation for any of the parts within this section

Depending on current regulatory requirements, a copy of the detailed inspection report may need to be submitted to IDNR, along with the Suggested Dam Inspection Report. The report and the Suggested Dam Inspection Report must be submitted to IDNR for all high hazard dam safety inspections.

4.3 WHAT TO LOOK FOR

4.3.1 Overview


Figure 4-14 Serious slide on an embankment dam.

The features the inspector should examine depend on the type of inspection and the type of dam (embankment, concrete, timber). A formal technical inspection will involve visual inspection of all dam features and general features around the dam. These features typically include embankment crest and slopes, principal and emergency spillways, outlets and drains, and miscellaneous features in the watershed. A maintenance inspection should also include inspection of all the dam features (see table 4-2).

Informal and special inspections usually focus on specific features and do not necessarily cover all of the dam features. However, it is recommended that informal inspections are performed frequently and cover as much of the dam and its structures as possible. The need to view site-specific features should be considered in preparing for the inspection.

Typically, the individual features of a dam will be visually examined and physically measured to determine the condition and to verify conformance with design or as-built plans. If data and plans are not available, the examination process will determine the characteristics, locations, and dimensions of the individual features. Modifications of features will be revealed during the examination. The relationship between the levels of the reservoir to the dam and its appurtenances on the day of the inspection is significant. Some features may not be visible at higher water levels. Seepage areas or other potential problems may not be readily apparent during an inspection when the reservoir level is low. Generally, all instrumentation systems should be inspected. The inspector should evaluate the condition of monitoring devices and collect data when appropriate for inspection purposes.

Embankment Dams (earthfill, rockfill)	Outlets & Reservoir Drains
Upstream slope Downstream slope Left and right abutments Crest Upstream & downstream groins Downstream toe Internal drainage outlets Riprap & other slope protection	Inlet structures Discharge conduit Discharge channel Outlet structures and stilling basins Joints Control features (gates, stoplogs, valves, bulkheads, hoists) Trash racks and debris control Drains (pressure relief) Erosion protection (riprap, vegetation, concrete, gabions) Access
Concrete Dams (arch, gravity, roller-compacted) Upstream face Downstream face Crest Left and right abutments Downstream toe Galleries Sluiceways and controls Relief drains	**General Areas** Submerged areas Mechanical and electrical systems (cables, generators, winches, etc.) Watershed and tributary stream channels Access Slope reinforcing and retaining structures Shoreline and hillsides Instrumentation Downstream hazard Upstream development Downstream channel obstructions Reservoir area Emergency power systems Hydropower facilities
Spillways (earth, rock, structural) Approach channel Inlets and control sections Discharge conduit Discharge channel Outlet structures and stilling basins Joints Control features (gates, stoplogs, flash boards) Trash racks and debris control Drains (pressure relief) Side slopes Sidewalls Erosion protection (riprap, vegetation, concrete, gabions)	**Timber Dams** All wood or timber features Ballast Abutment walls Downstream erosion control

Table 4-2 Typical Features that May Require Visual Inspection

The geologic features of any site such as abutments, foundations, and subsurface materials, are normally covered and cannot be directly examined. In order to evaluate geologic features, it is important to examine areas adjacent to both the dam and the reservoir for conditions which may indicate a problem. A complete review of all available geotechnical information for any dam is necessary to perform the inspection properly. A geophysical investigation may be required if the subsurface conditions warrant further inspection.

When individual features of a dam are examined, the inspector should look for typical conditions that indicate a problem may exist. The significance of these conditions will be discussed in the following Chapters. Visual observations may identify conditions of a serious nature that require immediate repairs, or other conditions that may indicate a minor problem that require only routine maintenance or monitoring. Findings from prior inspections can be used to identify conditions that existed previously. These findings are useful for comparison of the dam in its present state to denote any changes in the condition and its assessment.

Conditions to look for and the level to which the dam features can be examined will depend on many factors. The type of inspection will dictate the detail to which the conditions need to be evaluated. Access, seasonal and weather conditions, impoundment levels, and equipment availability may limit the evaluation. A cursory inspection may be made to check for changes in previously identified conditions. Specific conditions should be looked for following an extreme event such as an earthquake or major hydrologic event. The following paragraphs summarize the general types of conditions to look for.

4.3.2 Embankment Dams

Embankment dams are the most common type of dams in Indiana. Typical types of embankment dams include earthfill dams, homogeneous earthfill dams, rockfill dams, and zoned embankment dams. Common problems to look for on the various dam features are summarized below.

Upstream Slope - animal burrows, beaching, cracks, debris, depressions, erosion, paths and ruts, sinkholes, slides and scarps, sloughs, utilities, telephone cables, electric cables, and vegetation.

Downstream Slope - seepage, depressions, erosion, paths and ruts, sinkholes, slides and scarps, sloughs, animal burrows, buried pipes (water, sewer, gas), cracks, utilities, telephone cables, electric cables, and vegetation.

Left and Right Abutments - animal burrows, cracks, depressions, erosion, geologic features, paths and ruts, seepage, sinkholes, slides and scarps, sloughs, utilities, telephone cables, electric cables, and vegetation.

Crest - alignment, animal burrows, buried pipes (water, sewer, gas), cracks, displacements, paths and ruts, settlement, utilities, telephone cables, electric cables, and vegetation.

Upstream and Downstream Groins - animal burrows, erosion, paths and ruts, seepage, sinkholes, undermining, and vegetation.

Downstream Toe - animal burrows, cracks, depressions, erosion, paths and ruts, seepage and boils, sinkholes, sloughs, undermining, and vegetation.

Internal Drainage Outlets - cloudy drainage, metal corrosion, flow rate, obstructions, structural damage.

Riprap and Other Slope Protection - beaching, coverage, deterioration, riprap displacements, undermining, weathering, exposed or torn geotextile.

4.3.3 Concrete Dams

There are only a few concrete dams in Indiana. Concrete dams can be more hazardous to inspect than embankment dams due to the usual steep and wet faces. Typical concrete dams include arch dams, gravity dams, and roller-compacted dams. Common problems to look for on the various concrete dam features are summarized below.

Upstream Face - alignment, concrete condition (cracks, deterioration, spalling, and weathering), displacements, joint separation and deterioration, structural damage.

Downstream Face - alignment, concrete condition (cracks, deterioration, spalling, and weathering), displacements, joint separation/deterioration, seepage, structural damage.

Left and Right Abutments - cracks, displacements, erosion, geologic features, seepage, vegetation, weathering (rock).

Downstream Toe - cracks, seepage, undermining.

Galleries - cracks, displacements, efflorescence, joint separation, seepage.

Relief Drains - cloudy drainage, flow rate, obstructions.

Sluiceways and Controls - (See Spillway System and Outlets)

4.3.4 Spillway System (Earth, Rock, Structural)

All dams should have spillways to allow for the discharge of stormwater inflows. Spillways can be constructed in earth and lined with vegetation, geotextiles, or rock, or they can be constructed of structural materials such as concrete or concrete blocks. Spillways constructed in earth are open spillways. Spillways constructed with concrete materials can be open (open to the air, similar to a channel), or they can be closed spillways consisting of a drop inlet, or riser, connected to a discharge conduit. Closed spillways can also consist of a conduit placed through the embankment without the use of a riser. Closed spillways should always use a trash rack. Common problems to look for on spillway components are summarized below.

Approach Channel - alignment, obstructions, paths and ruts, sedimentation and siltation, vegetation, restrictive areas not designed as a control section.

Inlets and Control Sections - alignment, concrete condition (cracks, deterioration, erosion, spalling, weathering), deterioration (other materials), cracks, joint separation and deterioration, metal corrosion, obstructions, paths and ruts, settlement, spalling (rock), structural damage, vegetation.

Discharge Conduit - alignment, cavitation, concrete condition (cracks, deterioration, erosion, spalling), joint separation and deterioration, leakage, metal corrosion, obstructions, paths and ruts, seepage, settlement, structural damage, undermining, abrasion damage to the floor and walls, vegetation.

Discharge Channel - alignment, erosion, obstructions, paths and ruts, seepage and boils, vegetation, restrictive areas not designed as a control section.

Outlet Structures and Stilling Basins - alignment, concrete condition (cracks, deterioration, erosion, spalling, and weathering), debris, displacements, erosion, obstructions, seepage, structural damage, undermining, abrasion damage to the floor and walls.

Joints - alignment, concrete deterioration, metal corrosion, seepage, separation, damaged or missing seals.

Control Features - emergency operation, leakage, metal corrosion, operation, structural damage, timber, or wood deterioration.

Trash Racks and Debris Control - alignment, debris, metal corrosion, opening sizes, operation.

Drains (Pressure Relief) - cloudy drainage, flow rate, obstructions.

Side Slopes - geologic features, slides and scarps, sloughs, vegetation and vegetal cover, weathering (rock).

Sidewalls - alignment, concrete condition (cracks, deterioration, erosion, spalling, weathering), displacements, seepage, structural damage.

Erosion Protection - coverage, deterioration, structural damage, weathering.

4.3.5 Outlets and Reservoir Drains

Outlets and drains are used to drawdown the reservoir level in times of emergencies, for maintenance purposes, or when the need arises to lower the water for any reason. Outlet facilities are usually submerged or buried and are difficult to inspect. Common problems to look for on outlet components are summarized below.

Inlet Structures - alignment, concrete condition (cracks, deterioration, erosion, spalling, weathering), displacements, metal corrosion, obstructions, settlement, structural damage, operability (does it perform as designed?).

Discharge Conduit - alignment, concrete condition (cavitation, cracks, deterioration, erosion, spalling), displacements, joint deterioration and separation, metal corrosion, obstructions, seepage, settlement, structural damage.

Discharge Channel - alignment, erosion, obstructions, seepage and boils, vegetation.

Outlet Structures and Stilling Basins - alignment, concrete condition (cracks, deterioration, erosion, spalling, weathering), debris, displacements, obstructions, seepage, structural damage, undermining, operability (performing as designed).

Joints - alignment, concrete deterioration, metal corrosion, seepage, separation, voids, damaged or missing seals.

Control Features - emergency operation, leakage, metal corrosion, operation (performance and protection from unauthorized persons), structural damage, timber, or wood deterioration.

Trash Racks and Debris Control - alignment, debris, metal corrosion, opening sizes, operation.

Drains (Pressure Relief) - cloudy drainage, flow rate, obstructions.

Erosion Protection (discharge channel) - deterioration, structural damage, weathering.

Access - Condition of roadways, obstructions (potential), personnel safety (ladders, walkways, bridges, handrails), protection from unauthorized persons.

Emergency Systems - operation, location, and access.

4.3.6 General Areas

General areas basically include all other areas not listed above, such as upstream watershed areas, downstream channels and watershed areas, access roads, shorelines, and other appurtenant works and structures. Common problems to look for in general areas are summarized below.

Submerged Areas - debris, erosion and scour, structural damage, undermining.

Mechanical and Electrical Systems - backup systems, corrosion, deterioration, general condition, leakage (gates, valves, bulkheads), operation.

Watershed and Tributary Stream Channels - channel dimensions, diversions, erosion, land use (future conditions), obstructions, sedimentation, vegetation.

Downstream Channel Obstructions - bridge crossings, channel dimensions, erosion (slide potential), obstructions, sedimentation, vegetation.

Reservoir Area - bridge crossings, development (in high water zones), pipelines, subsurface mining, sedimentation, topography (areas below maximum pool elevation), vegetation, water quality, whirlpools, boat moorings or other features that may break loose and clog the spillway.

Emergency Power Systems - operation and access, backup systems.

Shoreline and Hillsides - beaching, erosion, depressions, land use, landslides, vegetation.

Instrumentation - collect data as required and check condition.

Downstream Hazard - present and future development.

Access - road conditions, gates and fences, downstream channel crossings.

Hydropower Facilities - diversion tunnels and by-pass systems, intake structures, operation, penstocks, release structures (tailrace), structural damage.

Slope Reinforcing and Retaining Structures - alignment, anchors, concrete condition (cracks, deterioration, spalling, weathering), displacements, joint separation and deterioration, structural damage.

4.3.7 Timber Dams

Timber dams are rare and were typically constructed in the past at mills. Timber is generally a poor construction material for dam embankments due to the tendency for it to rot. Common problems to look for on timber dam components are summarized below.

All Wood or Timber Features - alignment, displacements, undermining, wood deterioration and preservation.

Ballast - depressions, deterioration.

Abutment Walls - alignment, concrete condition (cracks, deterioration, spalling, weathering), displacements, joint separation and deterioration, seepage, structural damage.

Downstream Erosion Control - deterioration, structural damage, weathering.

CHAPTER 5.0

INSPECTION OF EMBANKMENT DAMS

5.0 INSPECTION OF EMBANKMENT DAMS

5.1 INTRODUCTION

The purpose of a dam inspection is to identify deficiencies that potentially affect the safety of the dam. For that reason, inspections are usually referred to as dam safety inspections. As described in previous chapters, there are four types of dam safety inspections that typically will be performed: formal technical, maintenance, informal, and special. This chapter covers all four types of inspections on embankment dams, but focuses on the embankment structure only. Additional embankment dam features, such as spillways, outlets, and general areas are covered under subsequent chapters.

The purpose of this chapter is to help owners and inspectors identify conditions that threaten the safety and long life of the dam. Although some of these conditions can be corrected by normal maintenance, more serious deficiencies may require further investigation by qualified professionals with expertise in specific areas of concern. The end of this chapter contains sketches that can be used to help the owner or inspector identify and classify problems found on the embankments of dams.

Embankment dams include any dam constructed of natural soil materials. This includes the following general types of dams:

Earth Dam (or earthfill dam) - An embankment dam in which more than 50% of the total volume is formed of compacted inorganic soil material obtained from a borrow area (see Figure 5-1).

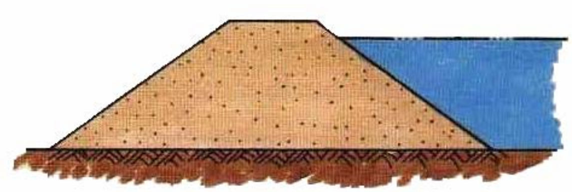


Figure 5-1 Earth embankment dam.

Homogeneous Earthfill Dam - An embankment dam constructed of similar earth material throughout, except for possible inclusion of internal drains or drainage blankets; distinguished from a zoned earthfill dam.

Hydraulic Fill Dam - An embankment dam constructed of materials, often dredged, that are conveyed and placed by suspension in flowing water (rare). Hydraulic fill dams are not recommended and are prone to instability problems.

Rockfill Dam - An embankment dam in which more than 50% of the total volume is comprised of compacted or dumped pervious natural or crushed rock.

Rolled Fill Dam - An embankment dam of earth or rock in which the material is placed in layers and compacted by using rollers or rolling equipment.

Zoned Embankment Dam - An embankment dam, which is composed of zones of selected materials having different degrees of porosity, permeability, and density.

The visual inspection procedures and information presented in this chapter can be applied to all the various types of embankment dams encountered. The information is presented for each feature of the embankment, including the crest, upstream slope, downstream slope, abutments, and groins.

The conditions or problems that may be encountered on embankments can vary depending on the location. For example, seepage typically occurs on the downstream slope areas and in the abutments and groins, whereas beaching and damage from wave action occur on the upstream slope. Some types of problems can develop anywhere on the embankment, such as inappropriate vegetative growth, cracking, or erosion. Tailwater on the downstream slope of an embankment can saturate the soils and lead to embankment instability; the potential for backwater should be considered.

Typically, the cause of the problem and potential safety concerns should be determined before any repairs are made on dams. However, if the problem is severe or an emergency is developing, emergency response actions may be required immediately. Short-term repairs, downstream notification, and other measures may be required in such instances (refer to Part 2). Short term measures may include water level lowering, embankment stabilization, spillway enlargement, or controlled breaching if the situation becomes critical.

Inspecting dams to identify and resolve the concerns addressed in this chapter can minimize or eliminate the chance of dam deterioration or failure. The inspector should be on the lookout at all times for any conditions that could contribute to dam failure.

5.2 ITEMS OF CONCERN

Some of the more common conditions that may be encountered during visual inspection of the embankment include longitudinal and transverse cracking, desiccation cracking, depressions, settlement, slides, seepage, lack of protection from wave action, erosion, inappropriate vegetation, tree root penetration, poor maintenance, ponding water, animal burrows, and debris. Many of these concerns are interrelated and occur in conjunction or as a result of each other.

The dam inspector should visualize worst-case conditions (i.e., design storm event is occurring) when looking for potential problem areas. For example, he/she should consider maximum loadings on roads and other structures, maximum water levels in the reservoir, peak discharge rates from spillways, discharge through the emergency spillway, winter icing conditions, etc.

The dam's crest usually provides the primary access for visual inspection and maintenance. Since surface water will pond on the crest unless that surface is well maintained, this part of the dam may require periodic regrading. Problems found on the crest should not be graded over without determining the cause. When a questionable condition is found, it should be evaluated and a qualified dam safety professional should be consulted if necessary. Quick corrective action applied to conditions requiring attention will promote the safety and extend the useful life of the dam while possibly preventing costly future repairs.

Figure 5-2 Embankment slope inspection can be hindered with excessive vegetation.

The upstream slope needs a thorough visual inspection, since the slope protection, vegetation, debris, and reservoir water can hide problems. Anytime the reservoir is emptied, the slope should be thoroughly inspected for settlement areas, animal burrows, sinkholes, or slides. Also, the reservoir basin (bottom of the reservoir) should be inspected for sink holes or settlement anytime the reservoir is emptied.

The downstream slope is especially important during visual inspection because it is the area where evidence of developing problems appears most frequently. The downstream slope requires detailed visual inspection. In order to assure the safety of the dam, it is important to keep this area free from obscuring vegetative growth. When cracks, slides or seepage are noted in this area, the cause should be determined and corrective action should be recommended immediately.

5.3 CRACKS AND SLIDES

5.3.1 Overview

Cracks and slides may indicate serious problems within the embankment. Looking for and spotting cracks may be difficult. The slope must be traversed in such a manner that the inspector is likely to walk over the cracks. If the embankment is covered with heavy brush or vegetation, a more concentrated search must be made to identify cracks. Slides are usually easy to identify.

Figure 5-3 Longitudinal cracks on embankment slope.

Cracks on embankments are divided into three categories in this chapter: longitudinal cracks, transverse cracks, and desiccation cracks. Cracks in the embankment are often the beginning of a slide, and cracks further weaken the soil strength by allowing more water to enter the embankment. To help distinguish drying (desiccation) cracks from other types of cracks, the ground surface adjacent to the dam should be examined for similar cracking patterns. Cracks should always be taken seriously, and the cause of the cracking should be determined so that the correct remedy can be developed.

Cracks may be only an inch or two wide but 2 or 3 feet deep. Usually a depth of 2 or more feet indicates that a serious condition is present. Shallow cracks may be harmless desiccation cracks. All cracks over 12 inches deep should be closely inspected and evaluated.

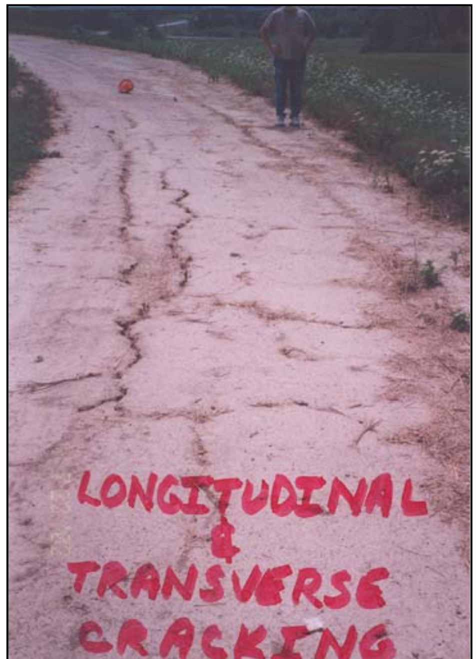


Figure 5-4 Inspection photograph indicating longitudinal and transverse cracking on crest of embankment.

Cracks may indicate possible foundation movement or failure, the beginning of embankment failure, or a surface slide. For example, a 20-foot-long line of recently dislodged riprap along the upstream slope could indicate a crack underneath the riprap.

5.3.2 Longitudinal Cracks

Longitudinal cracking may indicate localized instability, differential settlement, foundation settlement, and movement between adjacent sections of the embankment. In recently built structures, longitudinal cracks may indicate inadequate compaction of the embankment during construction. This form of cracking can occur anywhere on an embankment. Longitudinal cracking is characterized by a single crack or a close, parallel system of cracks along the crest or slope in a direction more or less parallel to the length of the dam. These cracks, which are continuous over their length and are usually greater than 1 foot deep, can be differentiated from drying cracks which are usually intermittent, erratic in pattern, shallow, very narrow, and numerous. Longitudinal cracking usually signals the early stages of a slide or slough, and may precede vertical displacement as the dam attempts to move to a position of greater stability. In this case, the crack usually develops into a scarp which forms during movement of unstable slopes. Vertical displacements on the crest are usually accompanied by displacements or bulging on the upstream or downstream faces of the dam.

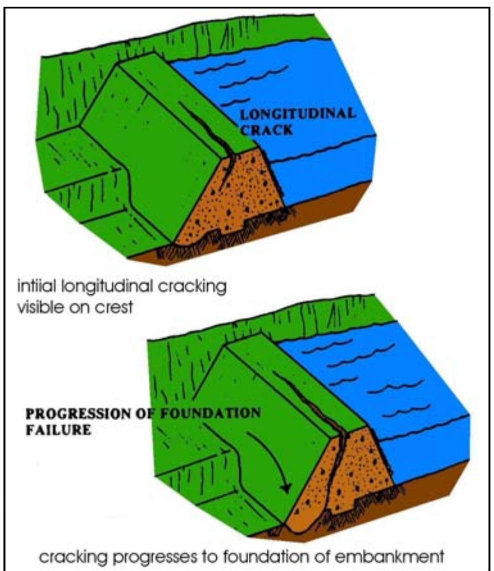


Figure 5-5 Longitudinal cracking may indicate foundation failure.

Longitudinal cracks can allow stormwater and reservoir water to enter the embankment. When water enters the embankment, the strength of the embankment material adjacent to the crack may be lowered. The lower strength of the embankment material can lead to or accelerate slides and slope stability failure.

Longitudinal cracks usually get worse with time due to rainfall, seepage, and the decreasing strength of the embankment and foundation materials. When the soil is weakened sufficiently, or the soil below the crack becomes saturated, sloughing or sliding will occur. As the soil becomes saturated it gets heavier, resulting in an increased tendency for the soil mass to move downward. Weakening and removal of foundation materials by water movement will also cause increased settlement of the embankment resulting in increased cracking.

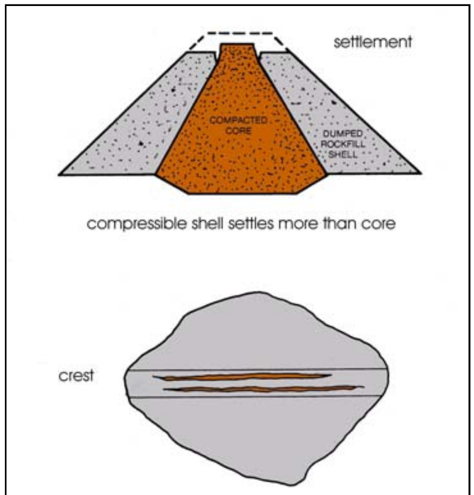


Figure 5-6 Longitudinal cracking due to differential embankment settlement.

If longitudinal cracking is observed during a visual inspection, the following actions should be taken:

- Photograph and record the location, depth, length, width, and offset of each crack observed. Stakes should be placed at the ends of the cracks, and the distance between the stakes measured and recorded. Compare observations with previous results.
- Closely monitor the crack for changes and scarping.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe, or gets progressively worse.

5.3.3 Transverse Cracks

Transverse cracking may indicate differential settlement or movement between adjacent segments within the embankment or the underlying foundation. Transverse cracking is usually a single crack or a close, parallel system of cracks which extend across the crest in a direction more or less perpendicular to the length of the dam. This type of cracking is usually greater than 1 foot in depth and can easily be distinguished from drying cracks. Transverse cracking poses a definite threat to the safety and integrity of the dam. If the crack should progress to a point below the reservoir water surface elevation, seepage could occur along the crack and through the embankment cross-section. This could evolve into a piping situation, and if not

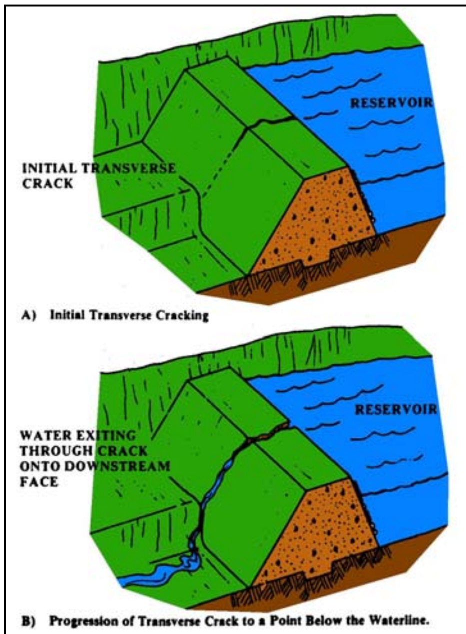


Figure 5-7 Progression of transverse cracking.

corrected, lead to breaching of the dam.

Transverse cracking frequently develops when compressible material overlies abutments consisting of steep or irregular rock, or when areas of compressible or erosive material are in the foundation. Soft or weathered rock formations in the foundation may collapse or erode from ground water action, leading to embankment settlement. Limestone is another potentially hazardous foundation material that can dissolve in groundwater, creating voids that can lead to embankment settlement. For this reason, dams in karst areas may be particularly hazardous.

If transverse cracking is observed during a visual inspection, the following actions should be taken:

- Photograph and record location, depth, length, width, and offset of the cracks. Stakes should be placed at the ends of the cracks, and the distance between the stakes measured and recorded.
- Closely monitor the cracks for changes.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe or gets progressively worse. Serious transverse cracking or repair operations usually require lowering the reservoir level.

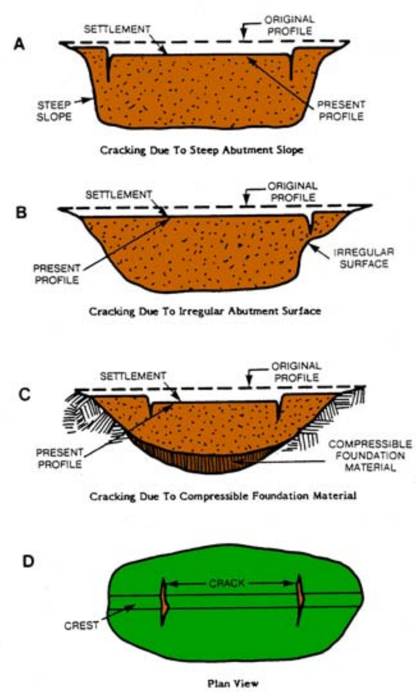


Figure 5-8 Transverse cracking due to differential settlement within embankment.

5.3.4 Desiccation Cracks

Desiccation cracking is caused by the drying out and shrinking of certain types of embankment soils, usually highly plastic soils that contain a large percentage of clay. Desiccation cracks usually develop in a random, honeycomb pattern on the crest and the downstream slope. Desiccation cracks may be oriented longitudinally or transversely, or both. This type of cracking may also develop on the upstream slopes above the water level. Although not normally used in embankment construction, silts will also display desiccation cracking if exposed to drying. As an example, desiccation cracking can be observed in “mud puddles” that completely dry out, leaving behind a series of cracks in the bottom of the puddle.

Figure 5-9 Desiccation cracking.

The worst desiccation cracking develops when a combination of the following two factors is present:

(1) A hot, dry climate accompanied by long periods in which the reservoir remains lowered or empty.
(2) An embankment that is composed of highly plastic soil, such as clay.

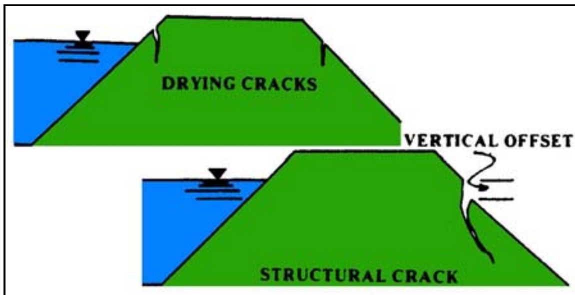


Figure 5-10 Desiccation cracks are much smaller than structural cracks.

Usually, desiccation cracking is not harmful unless it becomes severe. The major threat of severe desiccation cracking is that this type of cracking can contribute to the formation of gullies. Surface runoff erosion concentrating in the desiccation cracks or gullies can result in eventual damage to the dam. Also, heavy rains can fill up these cracks and cause portions of the embankment to become unstable and to slip along crack surfaces where the water has lowered the strength of the embankment material. Deep cracks that extend through the core conceivably can cause a breach of the dam when the reservoir rises and the cracks fail to swell rapidly enough to reseal the area.

If desiccation cracking is observed during a visual inspection, the following actions should be taken:

- Probe the more severe cracks to determine their depth.
- Photograph and record the location, depth, length, and width of any severe cracks observed.
- Compare the measurement of the crack dimensions with past measurements to determine if the condition is worsening.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas. Usually repairs by sealing and grading are adequate.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe or gets progressively worse.

5.3.5 Slides

Slides have various names including displacements, slumps, slips, and sloughs. Slides can be grouped into two major categories: shallow slides and deep-seated slides. Shallow slides are called sloughs, or sloughing. Slides develop when the strength of the soil in the embankment is less than the forces that cause slope failure. Steep embankment slopes, poor soil compaction, improper soil composition, excessive water in the soil, and seepage contribute to slides.

Shallow slides on the upstream slope are often the result of an overly steep slope and/or poorly compacted soils. These conditions can be aggravated by a rapid lowering of the reservoir. Shallow slides on the upstream slope usually pose no immediate threat to the integrity of the dam. However, shallow slides may lead to the obstruction of water conveyance structure inlets and larger, deep-seated slides.

Figure 5-11 Shallow slide at toe of embankment resulting from excessive seepage and poor compaction.

Shallow slides on the downstream slope also indicate an overly steep slope or poorly compacted soils. In addition, these slides may also indicate a loss of strength in the embankment material. A loss of strength in the embankment material can be the result of saturation of the slope from either seepage or surface runoff. Additional loads from snow banks or structures can aggravate the condition. The owner or inspector should consult a qualified dam safety professional if he/she is unsure whether the slide presents a serious threat to the integrity of the dam.

Deep-seated slides are serious threats to the safety of the dam. Deep-seated slides may be recognized by the presence of a well-defined scarp or bulging on the slope or at the toe. Arc-shaped cracks on the slope are usually indications that a slide is beginning. This type of crack may develop into a large scarp at the top of the slide.

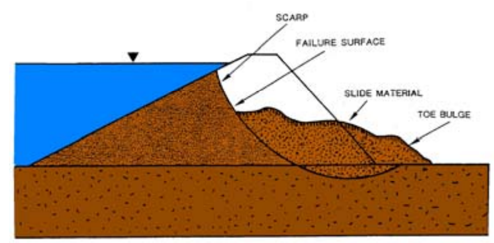


Figure 5-12 Deep-seated slide.

Bulging is usually associated with the lateral spreading of the dam or with slides. Bulging as a result of lateral deformation is accompanied by settlement of the crest and a potential loss in dam freeboard. The bulging is most evident at the toe of the dam. If the inspector suspects a loss of freeboard, a survey of the crest should be performed to verify if there has been a loss of freeboard. The area above a bulge should be examined carefully in order to identify other indicators of instability such as cracks and scarps. Not all bulges indicate a stability problem. When the dam was constructed, it may not have been uniformly graded by the dozer or grader operator, so there may be bulges in the embankment that were formed during construction. The inspector should determine the cause of the bulging and recommend a course of action. Bulging associated with slides is a more serious problem. If bulging associated with cracks or scarps is observed, a qualified dam safety professional should be contacted immediately.

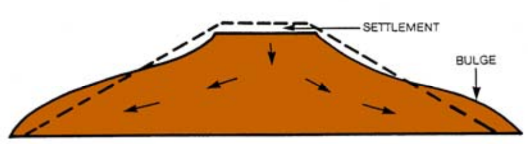


Figure 5-13 Bulging and associated crest settlement.

Slides are usually easy to spot and require immediate evaluation by a qualified dam safety professional if they are large or are continuing to show movement. However, slides may be difficult to spot if a scarp has not developed. Their appearance may be subtle, since there may be very little settlement or bulging out from the normal slope. A good familiarity with how the slope looked at the end of construction will help identify any new slides. Figures 5-11 and 5-14 illustrate slides on the downstream slope, with vertical and horizontal movement and the formation of a scarp.

Most slides have early warning signs that allow their detection. They usually develop over a period of time, beginning with some form of surface cracking, followed by measurable vertical displacement and scarping, and potentially ending in complete failure of the embankment or slope. A bulge in the embankment and vertical displacement at a crack in the embankment are usually signs of sliding. Stormwater falling onto or running into the slide area may make conditions worse and accelerate the instability of the slope. Longitudinal and arc-shaped cracks are usually a symptom of impending slides.

Figure 5-14 Large slide on embankment with prominent scarp.

If a slide or bulge is observed during a visual field inspection, the following actions should be taken:

- Photograph and record the location, depth, length, width, and height of scarp for each slide or bulge observed. Stakes should be placed at the ends of the scarp, and the distance between the stakes measured and recorded.
- Look for any surrounding cracks, especially uphill from the slide.
- If a bulge is present, closely inspect the area above the bulge for cracking or scarps which indicate that a slide is the cause. Probe the bulge to determine if material is excessively moist or soft. Excessive moisture or softness usually indicates that a slide is the cause.
- Look for evidence of seepage or saturated soils in or below the slide. Probe the entire area to determine the condition of the surface material.
- Closely monitor the slide for changes.
- Consult a qualified dam safety professional to determine the cause of the slide if it is severe.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas.
- In most instances, deep-seated slides will require the lowering or draining of the reservoir to prevent the possible breaching of the dam.

5.4 DEPRESSIONS

Figure 5-15 Settlement on embankment crest.

Depressions can be minor or they can be very serious. Sinkholes are a serious type of depression and are cause for alarm. A good way of distinguishing between minor depressions and sinkholes is to look at their profiles. Minor depressions have gently sloping, bowl-like sides, while sinkholes usually have steep, bucket-like sides. Some areas that appear to be depressions may be the result of improper final grading following construction. Settlement on the crest is a serious form of depression that can result in lowering of the embankment, creating a potential for overtopping. Although most minor depressions do not represent an immediate danger to the dam, they may be early indicators of more serious problems. Depressions may also result in water ponding on the crest of the embankment which may lead to stability problems due to soil saturation in the embankment.

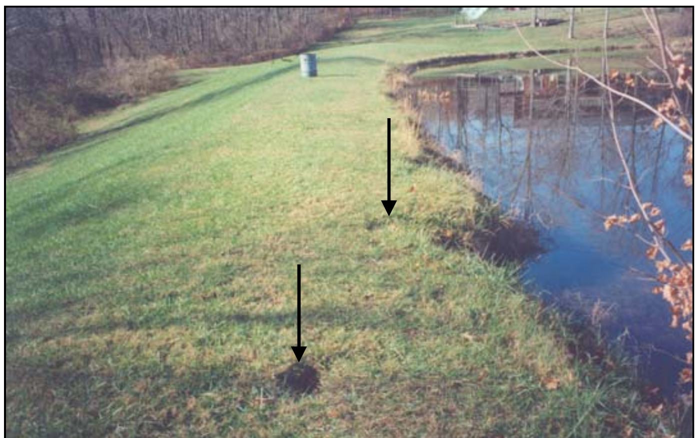


Figure 5-16 Sinkholes developing from muskrat burrows.

Depressions can be serious safety concerns and are typically caused by:

- Localized settlement in the embankment or foundation.
- Embankment spreading in the upstream and/or downstream direction. This type of spreading may result in a loss of freeboard or reservoir capacity, and can cause overtopping of the dam.
- Erosion - wave action against the upstream slope that removes embankment fines or bedding from beneath riprap may form a depression as the riprap settles into the vacated space. This may only appear on the upstream slope, or may spread to the crest if the damage is severe.
- Piping – soil piping may cause surface soils to collapse into the voids created by the piping, creating sinkholes.
- Animal burrows – surface soil falling into animal burrows can create depressions or sinkholes.

Depressions and other misalignments in the crest (and embankment slopes) often can be detected by sighting along fixed points. The inspector should sight and take photographs along guardrails, parapet walls, or pavement striping. Some apparent misalignment may be due to irregular placement of the fixed points. For this reason, irregularities should be evaluated over time to verify suspected movement. Sighting irregularities is facilitated by surveying permanent monuments across the crest to determine the exact location and the extent of misalignment. A record of survey measurements also can establish the rate at which movement is occurring.

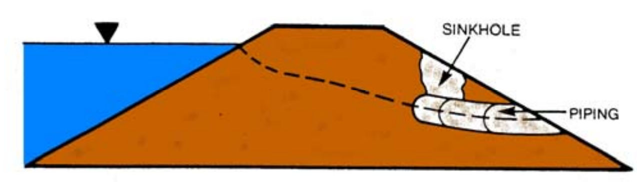


Figure 5-17 Sinkhole caused by animal burrow.

Sinkholes are a serious type of depression that can result in hazardous embankment safety conditions. Sinkholes are formed when the removal of subsurface embankment or foundation material has caused overlying material to collapse into the resulting void. The presence of a sinkhole may indicate that material has been transported out of the dam or foundation through the process of piping. In addition, animal burrows, and flowing water under pipes, walls, and slabs can contribute to the formation of sinkholes. The decomposition of embedded wood or other vegetative matter in the embankment also can cause sinkholes. If the embankment depressions or settlement progresses to a level below the normal pool elevation, the reservoir may overtop the embankment, resulting in breaching or total embankment failure. Settlement also reduces the storage capacity and freeboard of the dam which could result in overtopping, breaching, or failure during storm events.

If a depression is observed during a visual inspection, the following actions should be taken:

- Photograph and record the location, size, and depth of the depression.
- Probe the floor of the depression to determine whether or not there is an underlying void. An underlying void is indicative of a sinkhole.
- Frequently observe the depression to monitor its development.
- Consult a qualified dam safety professional to determine the cause of the depression if it is severe, or gets progressively worse.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas.

5.5 INADEQUATE SLOPE PROTECTION

Slope protection is designed to prevent erosion of the embankment slopes, crest, and groin areas. Inadequate slope protection usually results in deterioration of the embankment from erosion, and in the worst cases, can lead to dam failure. The inspector should look for inadequate slope protection, including eroded and displaced materials, and lack of vegetation during every visual inspection.

The two primary types of slope protection used on embankment dams include vegetative cover (grass) and riprap (rock). Grass cover is usually used on most embankment surfaces, while riprap is commonly used on the shoreline of the upstream slope. Soil cement, concrete, asphalt, articulated concrete blocks, and other types of slope protection also may be used. The type of slope protection selected depends upon economics, how the dam is used, and the prevailing conditions found at the site. A good growth of grass on an embankment provides excellent protection against erosion caused by rainfall and runoff. Deep-rooted grass that can tolerate repeated wetting and drying cycles should be used on embankments. Figure 5-19 shows an embankment experiencing shoreline erosion as a result of inadequate slope protection. The shoreline has no riprap and insufficient vegetative cover.

Figure 5-18 Riprap protection on the embankment slope at the shoreline, with grass on the rest of the slope.

Figure 5-19 Inadequate slope protection resulting in shoreline erosion.

A lack of vegetative cover or insufficient vegetative cover will result in rapid deterioration of the embankment from erosion. A lack of riprap, or improperly designed riprap along the shoreline can result in erosion of the shoreline soils if riprap is needed to protect the soil against wave action. It should be noted that not all dams will require riprap shoreline protection.

Riprap should be properly sized and placed to provide protection from erosion caused by wind or wave action, surface runoff erosion, and wind scour. Properly designed upstream riprap slope protection is made up of at least two layers of material: (1) an inner filter layer or bedding to keep the underlying soil from washing away; and (2) an outer rock layer to prevent erosion. The inner filter layer could be sand or fine aggregate, or a geotextile.

When deficiencies prevent riprap from providing erosion protection, the soil embankment beneath the riprap is exposed to erosion damage. Undercutting by wave action, slides, and slope failure can lead to failure of the upstream slope, a spillway channel, a plunge pool, or, if erosion continues unchecked, the breaching of the embankment. The inspector should look closely for signs of soil erosion and undercutting in all riprap areas.

If inadequate slope protection is observed, the inspector should:

- Photograph and record the location, size, and extent of the area of concern.
- Determine the cause of the problem, if possible.
- Recommend appropriate corrective action be taken to repair or to replace the damaged areas. Monitor the area if immediate repairs are not feasible (e.g., wrong season for planting grass).

5.6 WEATHERING AND EROSION

Figure 5-20 Erosion rills on the downstream slope of an embankment dam.

Erosion is a natural process, and its continuous forces will eventually wear down almost any surface or structure. Consequently, the dam inspector should always be on the lookout for signs and causes of erosion so that corrective action can be applied to halt its progression. Surface runoff erosion is one of the most common problems on embankment structures. If not corrected, surface erosion can become a more serious problem. During the visual inspection, the inspector should make sure that the slope protection is adequate to prevent erosion. He/she should look for beaching, scarping, and degrading of the slope protection, as well as erosion of the dam soil materials.

The worst damage from surface runoff is manifested by the development of deep erosion gullies on the slopes and groins of both upstream and downstream slopes. Severe gullies can cause breaching of the crest or shorten the seepage path through the dam, possibly leading to piping. Gullies can develop from poor grading or sloping of the crest that leads to improper drainage, causing surface water to collect and to run off at the low points along the upstream and downstream shoulders. Gullies caused by this type of runoff eventually can reduce the cross-sectional area of the dam.

Bald areas or areas where the protective cover is sparse are more susceptible to surface runoff erosion problems. On the upstream slope, erosion may undermine the riprap and cause it to settle. Settlement of the riprap may lead to the eventual degradation of the slope itself.

Shallow erosion rills (less than 6 inches deep) are common on many earth embankments. The formation of rills is difficult to stop, especially on long slopes. Stormwater runoff will tend to concentrate at one or more locations and form preferred flow paths, resulting in surface soil erosion in the form of rills and gullies. Shallow rills usually do not present a safety concern, but they should be monitored and repaired if they worsen. These conditions should be inspected following large or long storm events. Shallow rills will often have grass growing in them, indicating that the problem is minor. If the vegetation has been eroded and removed from the rills exposing the bare soil, the rills will probably get larger every time stormwater runoff flows through them. Repair of rills may do more harm than good to the slopes when trying to repair minor erosion damage, so sound judgment will be needed when recommending and scheduling repairs of this type of damage (e.g., do not perform repairs when the slopes are saturated, or when the damage is minor and does not show signs of accelerated damage).

Even the best designed erosion protection will usually experience some kind of degradation over time. Degraded riprap or other types of embankment protection should be monitored. If evidence shows that serious damage to the embankment is occurring, degraded slope protection must be repaired or replaced.

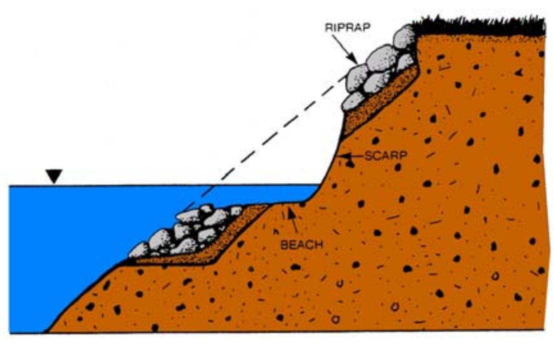


Figure 5-21 Wave action can remove riprap if it is not properly designed. This sketch shows beaching and formation of a scarp.

The constant action of waves on the upstream slope may result in beaching, scarping, and degrading of the slope protection, including riprap. Unless measures are taken to maintain adequate slope protection, wave action may begin to erode the embankment material.

Beaching is the removal of a portion or portions of the upstream slope of the embankment by wave action. Figures 5-21 and 5-22 show the effects of erosion and beaching on the upstream slope of a dam. When beaching occurs, embankment material is deposited farther down the slope. In this extreme form of erosion, the slope protection (i.e., riprap or vegetative cover) and underlying material are removed. A relatively flat beach area with a steep back slope, or scarp, is formed. Scarps should be monitored regularly for additional deterioration and repaired if conditions get worse.


Figure 5-22 Beaching is progressing on an unprotected shoreline


Figure 5-23 Cattle grazing on a dam embankment can lead to erosion problems.

Severe beaching could lessen the width, and possibly height of the embankment, leading to increased seepage, instability, or overtopping of the dam. Riprap installations in areas exposed to numerous freeze-thaw cycles or high winds are most likely to experience problems. The inspector should be alert for riprap problems if the dam is exposed to these conditions.

Adequate erosion protection is also required along the contact between the embankment and the abutments. Runoff from rainfall concentrates in these groin areas and can reach erosive velocities because of the steep slopes. Berms on the upstream or downstream face that collect surface water and empty into the groins add to the runoff volume. The inspector should examine these areas closely.

Erosion adjacent to groins results from improper construction or design, where the finished flow line of the groin is too high with respect to adjacent ground. This condition prevents all or much of the runoff water from entering the groin. The flow concentrates alongside the groin, erodes a gully, and may eventually undermine the lining in the groin. When examining the groins for erosion, the inspector should make sure that: (1) the channel in the groin has adequate capacity; (2) adequate protection and a satisfactory filter have been provided; (3) surface runoff can enter the groin channel; and, (4) its outlet is adequately protected from erosion.


Figure 5-24 Vehicle traffic can kill vegetation and result in erosion.

There are a number of special circumstances that can contribute to or initiate surface erosion of the crest and downstream slope. In some areas, livestock may establish trails on the embankment. Livestock traffic can damage the slope's vegetative cover. Recreational vehicles can cause ruts in the crest and can damage the slope protection. The inspector should be aware of any unique problems that may be common in a particular location or past problems that were noted on previous dam inspections.

During the visual inspection, the inspector should:

- Make sure that the slopes and crest protection is adequate to prevent erosion. Bald areas or areas where the surface protection is sparse are more susceptible to surface runoff problems.

- Look for beaching, scarping, and degradation of riprap or other materials used on the upstream slopes.
- Look for gullies, ruts, or other signs of surface runoff erosion. Be sure to check the low points along the upstream and downstream shoulders and groins since surface runoff can concentrate in these areas.
- Check for any unique problems, such as livestock or recreational vehicles that may be contributing to erosion.

If weathering and erosion are observed, the inspector should:

- Record the findings and photograph the area.
- Determine the extent, severity, and cause of the damage. Measure gullies, rills, and other erosion damage so that its progression can be monitored if necessary.
- Recommend that corrective action is taken to repair the areas damaged by surface runoff and that measures are taken to prevent more serious problems.
- If shorelines need repaired, or extensive embankment excavation is required, the reservoir level may need to be lowered.
- Consult a qualified dam safety professional if necessary.

5.7 INAPPROPRIATE VEGETATIVE GROWTH

Inappropriate vegetative growth is another common embankment problem. Inappropriate vegetative growth generally includes insufficient vegetation, excessive vegetative growth, and deep-rooted vegetation.

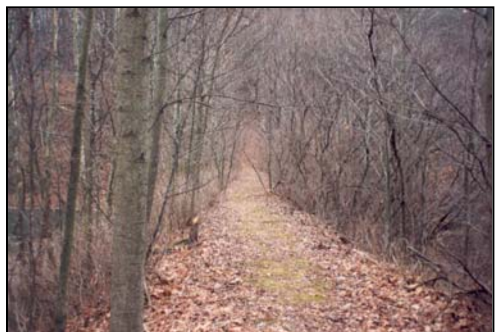


Figure 5-25 Trees and brush on an embankment pose a stability risk and can impede visual inspection.

Insufficient vegetation exposes the embankment soil which can lead to accelerated erosion. Insufficient vegetative cover may be a result of soil conditions, environmental conditions, or damage resulting from traffic on the embankment. Soil conditions usually include the lack of sufficient plant nutrients or poor soil composition. Poor soil conditions can be corrected in most cases. Environmental conditions are usually uncontrollable and include extreme heat and dry weather, excessive rainfall, and high winds that can remove fine-grained soils. Repeated vehicular and animal traffic can completely destroy the grass on embankments, leaving bare soil roadways or paths which are susceptible to accelerated erosion if left uncorrected.

Insufficient vegetation on the embankment slopes can progress to serious problems if left uncorrected for extended periods of time. These conditions should be recorded during a visual inspection along with recommendations for corrective action. The recommendations should also include a proposed timeframe for completing the repairs.

Figure 5-26 Insufficient vegetation on embankment crest and slopes will result in accelerated erosion.

Excessive vegetation is a problem wherever it occurs on an embankment dam. Excessive vegetation can obscure large portions of the dam, preventing adequate visual inspection. Problems that threaten the integrity of the dam can develop and remain undetected if they are obscured by vegetation. Excessive vegetation can also prevent access to the dam and surrounding areas. Limited access is an obvious problem both for visual inspection and maintenance, and especially during emergency situations, when access is crucial. Excessive vegetation can provide a habitat for rodents and burrowing animals, posing a threat to embankment dams by creating tunnels and potential seepage paths.

There should be no vegetation in the riprap on the upstream slope. Vegetation in the riprap promotes displacement and degradation of the slope protection. Vegetative growth should be controlled by periodic mowing or other means.

No trees or shrubs should be allowed on any embankment surfaces, or within 25 feet of the abutment contacts. Grass cover should be kept less than 12 inches high at all times. Crown Vetch and Kudzu should not be used on embankment surfaces, and if present, should be removed and replaced with more appropriate grasses.

Figure 5-27 Excessive vegetation around this riser and trash rack makes visual inspection almost impossible.

Although a healthy cover of grass is desirable as slope protection, the growth of deep-rooted vegetation, such as large shrubs and trees, is undesirable. Large trees could be blown over and uprooted during a storm. The resulting cavity left by the root system could reduce the embankment top elevation, breach the dam or shorten the seepage path and initiate piping. Accelerated soil erosion will also develop in the cavity left by an uprooted tree due to the exposed soil surfaces. The cavity left by the uprooting of a tree should be repaired immediately. The method of cavity repair will depend on the size of the tree and the location of the tree on the embankment.

Root systems associated with deep-rooted vegetation (trees, shrubs) develop and penetrate into the dam's cross section, causing damage to embankment and spillway structures. When the vegetation dies, the decaying root system can provide paths for seepage and cause piping to occur. Even healthy root systems of large vegetation can pose a threat by providing seepage paths. These seepage paths eventually can lead to internal erosion and threaten the integrity of the embankment. Generally, trees and shrubs more than 2 feet in height are undesirable growing on or adjacent to embankment dams. The best approach to trees on the crest, slopes, and adjacent to the dam is to cut them down or pull them out before they reach significant size. When and how to remove well-developed trees and root systems that are already in place on the dam depends on the size and location of the tree. If large trees have been cut down, but the stumps and/or root system have not been removed, carefully inspect the areas where the trees were for signs of seepage. The roots that are left behind may rot over time resulting in potential seepage paths. Part 2 of the Indiana Dam Safety Inspection Manual describes methods for removal and repair of trees and their damaging effects.

Figure 5-28 A tree is growing over the top of this spillway conduit.

During the visual inspection, the inspector should:

- Look for excessive and deep-rooted vegetation on all areas of the dam, and within 25 feet of the abutment contacts.
- Look for trees and brush in the spillways, or near conduits.
- Look for insufficient grass covering and bare areas on earth embankments.
- Look for excessive grass growth; grass should be mowed regularly and kept below 12 inches in height.
- Make sure that there is no vegetation growing in the riprap on the upstream slope.
- Check for signs of seepage around any remaining stumps or decaying root systems on the downstream slope or toe area.

If inappropriate vegetation is observed, the inspector should:

- Photograph the area and record the findings.
- Note the size, location, and extent of the inappropriate vegetation, or inadequate vegetation.
- Recommend that corrective action is taken to repair inadequate vegetation, or to eliminate inappropriate vegetation, and that measures are taken to prevent the future growth of undesirable vegetation.
- Consult a qualified dam safety professional if help is needed.

5.8 DEBRIS

The collection of debris on and around the dam is usually not an immediate danger to the integrity of the dam. However, unattended debris can lead to serious problems. The buildup of brush and logs on the dam can obscure the upstream slope and can prevent adequate visual inspection. Debris can accelerate the process of degradation of the riprap or other slope protection by impact from wave action.

Figure 5-29 Excessive debris around the riser trash rack can reduce discharge capacity and increase water levels.

Figure 5-30 A beaver has blocked the spillway on this dam.

Debris can clog or block spillway and outlet systems, resulting in potential dam overtopping hazards. Woody debris can become waterlogged and sink, possibly blocking an outlet works, inlet, or spillway inlets. Floating debris can also clog trash racks on spillways with riser conduits. The blocking of these inlet structures can cause overtopping of the dam in the event of a flood.

Certain animals, such as beavers, can contribute to the accumulation of debris in and around the dam. Removal of debris is usually a relatively easy task.

If the inspector finds debris in and around the dam, he/she should:

- Determine the cause of the debris, and, photograph, record, and report observations.
- Recommend that appropriate corrective action is taken to remove the debris, and that measures are taken to prevent the future accumulation of debris.

Figure 5-31 Telltale signs of a muskrat burrow.

5.9 BURROWING ANIMALS

Animal burrows can be dangerous to the structural integrity of the dam since they may weaken the embankment and can create pathways for seepage. Animals that can cause destruction to embankment dams include groundhogs (woodchucks), muskrats, and ground squirrels.

Burrowing animals make nests and passageways in soil, including many dam embankments. The animal passageways can lead to piping in the embankment soils when they connect the reservoir to the downstream slope or penetrate the dam's core. Shallow burrows or burrows that are confined to one side of the embankment may be less dangerous than these deep or connective passageways. If shallow burrows are so prevalent that they honeycomb an embankment, the integrity of the embankment is suspect. A qualified dam safety professional should be consulted for serious cases to determine how the deficiency might be corrected. If burrowing animals are present, the inspector should photograph the area and record his/her findings, and recommend that measures be taken before serious damage occurs to the dam. Eradication or removal is usually the recommended course of action. The local IDNR conservation officer should be contacted to obtain additional guidance on controlling animals on dams.

Figure 5-32 Rodent burrow.

Rodents such as the groundhog (woodchuck), muskrat, and beaver are attracted to dams and reservoirs, and can be quite dangerous to the structural integrity and proper performance of the embankment and spillway. Groundhog and muskrat burrows weaken the embankment and can serve as pathways for seepage. Beavers may plug the spillway and raise the pool level. Rodent control is essential in preserving a well-maintained dam.

Figure 5-33 Groundhogs can make extensive burrows in an embankment.

The groundhog is the largest member of the squirrel family. Occupied groundhog burrows are easily recognized in the spring due to the groundhog's habit of keeping them "cleaned out." Fresh dirt is generally found at the mouth of active burrows. Half-round mounds, paths leading from the den to nearby fields, and clawed or girdled trees and shrubs also help identify inhabited burrows and dens. When burrowing into an embankment, groundhogs stay above the phreatic surface (upper surface of seepage or saturation) to stay dry. The groundhog usually burrows into the embankment from the downstream slope; the burrow is rarely a single tunnel. It is usually forked, with more than one entrance and with several side passages or rooms from 1 to 12 feet long. Groundhogs can be controlled by using fumigants or by removal from the site. Fumigation is the most practical method of controlling groundhogs. Removal may be preferable around buildings or other high fire hazard areas. Groundhogs will be discouraged from inhabiting the embankment if the vegetal cover is kept mowed.

The muskrat is a stocky rodent with a broad head, short legs, small eyes, and rich dark brown fur. Muskrats are chiefly nocturnal. Muskrats can be found wherever there are marshes, swamps, ponds, lakes, and streams having calm or very slowly moving water with vegetation in the water and along the banks. Muskrats make their homes by burrowing into the banks of lakes and streams or by building "houses" of rushes and other plants. Their burrows begin from 6 to 18 inches below the water surface and penetrate the embankment on an upward slant. At distances up to 15 feet from the entrance, a dry chamber is hollowed out above the water level. Once a muskrat den is occupied, a rise in the water level will cause the muskrat to dig farther and higher to excavate a new dry chamber. Damage (and the potential for problems) is compounded where groundhogs or other burrowing animals construct their dens in the embankment opposite muskrat dens.

Beaver will try to plug spillways with their cuttings. Typical signs of beaver at a dam are tooth-marked trees and stumps. Routinely removing the cuttings is one way to alleviate the problem. Another successful remedy is the placement of electrically charged wire or wires around the spillway inlet. Trapping beaver may be done by the owner during the appropriate season.

Figure 5-34 Telltale signs of a beaver.

Crawfish, mice, and moles are also very common on earth embankments. These animals live in small burrows which generally do not pose a threat to dam safety. Crawfish dig vertical holes from the ground surface to a level below the groundwater surface, or phreatic surface, in the embankment. These holes are small and are usually vertical only, so they normally do not create the potential for lateral water seepage through the embankment. However, in some instances, their holes have been observed to intercept the phreatic surface on the downstream embankment slope, resulting in concentrated water seepage from the dam. In these cases, removal of the crawfish and repair of the embankment may be required.

During the visual inspection, the inspector should:

- Look for signs of burrowing animals and beavers.
- Photograph and record signs of animal presence and damage they have caused.
- Recommend that appropriate corrective action be taken to remove the animals from the dam and to repair the damage.

5.10 SEEPAGE

5.10.1 Overview

Every embankment dam has water passing through or under the embankment because all earth materials are porous. The passage of water through or under the embankment is known as seepage. Seepage quantities and rates increase as the depth of the water in the reservoir increases due to the greater pressure upstream of the embankment.

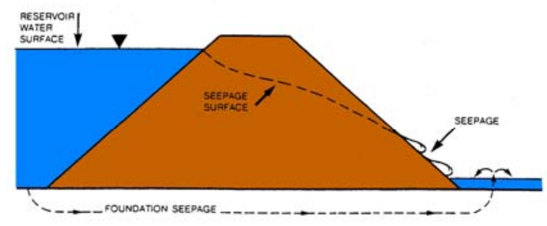


Figure 5-35 Seepage may occur through the embankment or the foundation.

Seepage becomes a problem when embankment or foundation materials are moved by the water flow, or when excessive pressure builds up in the dam or its foundation. Problem seepage is often referred to as uncontrolled seepage. Excessive seepage and pressure can result in slides and embankment instability. Slides and other embankment problems are often a direct result of seepage that has saturated and weakened the embankment soils. Problem seepage is a serious concern and should be corrected before embankment structural damage occurs.

5.10.2 Types and Location of Seepage

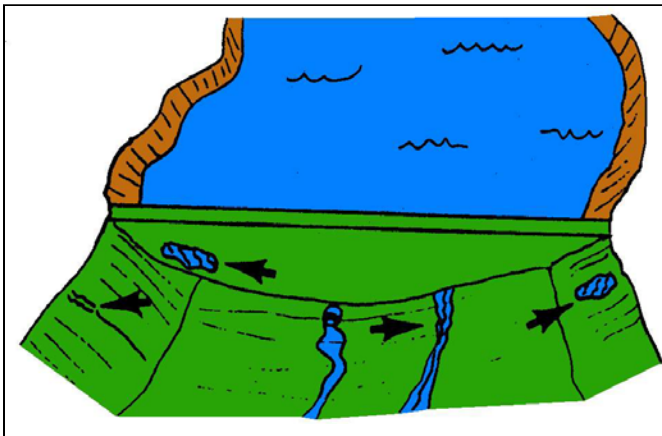


Figure 5-36 Common areas where seepage is observed.

Seepage can emerge anywhere on the downstream face, beyond the toe, or on the downstream abutments at elevations below normal pool. Seepage may vary in appearance from a soft, wet area to a flowing spring. It may show up first as only an area where the vegetation is more lush and darker green. Downstream groin areas should always be inspected closely for signs of seepage. Seepage can also occur along the contact between the embankment and a conduit spillway, drain, or other appurtenance. Slides in the embankment or an abutment may be the result of seepage causing soil saturation or excessive pressures in the soil pores.

Some water will seep from the reservoir through the foundation at most dams. Where it is not intercepted by a subsurface drain, the seepage will emerge downstream from or at the toe of the embankment. If the seepage forces are large enough, soil will be eroded from the foundation and be deposited in the shape of a cone around the outlet. If these “boils” appear, professional advice should be sought immediately. Seepage flow which is muddy and carrying soil particles is evidence of piping, and complete failure could occur within the near future if it is serious. Piping can occur along a spillway and other conduits through the embankment, and these areas should be closely inspected. Sinkholes that develop on the embankment may be signs that piping has begun, and could be followed by a whirlpool in the lake surface and then a rapid and complete failure of the dam. Emergency procedures, including downstream evacuation, may have to be implemented if this condition is noted.


Figure 5-37 Piping through the foundation; notice the turbid discharge.

A slow continuous drop in the normal lake level could be the result of evaporation or drawdown due to maintenance of minimum releases. However, an inexplicable continuous recession in pool level, or especially, a sudden drop in water level is usually an indication that serious problems exist and immediate attention is required. The entire embankment, the appurtenances, and the area downstream should be inspected for signs of increased seepage or flowing water. This condition may indicate a serious problem and will require frequent, close monitoring and the assistance of qualified professionals.

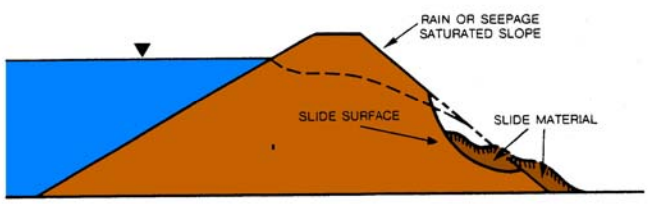


Figure 5-38 Uncontrolled seepage may result in slides and slope failure.

Uncontrolled seepage is a major cause of embankment dam failure. Seepage problems can be divided into two categories based on the type of problem it causes: stability problems, and piping problems. Seepage causes stability problems when high water pressure and saturation in the embankments and foundations cause the earth materials to lose strength. If uncontrolled seepage emerges on the lower downstream slope, the seepage will usually cause sloughing or massive slides. If seepage is concentrated through materials such as sands or cohesionless silts, the force of the flowing water can start to remove material at the exit point, and cause progressive erosion known as piping.

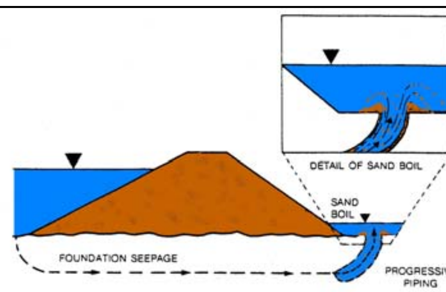


Figure 5-39 Sketch of progressive piping.

Piping usually starts at or near the downstream toe with the removal of the soil material at the seepage exit, or outlet. A sand boil may develop at the seepage outlet if the material being eroded is coarse silt or sand, however, not all piping creates sand boils. Sand boils may not occur when concentrated seepage occurs through an embankment, along the groins, or in contact with concrete structures. As piping progresses, soil erosion continues upstream, eroding a void, or pipe, through which the water flows. Erosion usually continues until the pipe extends all the way to the reservoir or other source of water. Severe piping problems can also occur when seepage moves embankment material into voids in rock foundations or rock fill portions of the dam.

Figure 5-40 Piping with clear discharge may indicate that no additional soil is being removed from the foundation.

It can be difficult to determine the source of seepage, since the exit may be the only visible condition observed. The seepage pipe shown in Figure 5-40 was observed a few feet below the toe of an earth embankment, and it was not clear whether the water was flowing through the embankment or under it. No sand or other soil was being carried by the seeping water, and the reservoir level was slowly getting lower, so the pipe was probably already formed. Seepage may originate in the bottom of the reservoir, upstream of the embankment, and travel through porous soil strata in the foundation of the dam.


Figure 5-41 This seepage has produced iron oxide stains.

Some seepage is difficult to detect since nothing is visible until the embankment starts to collapse, or until a vortex appears in the reservoir. A vortex is a rotational lake surface disturbance which could appear if water is rapidly conveyed through a seep or pipe. Formation of a vortex associated with a significant seep or piping through an embankment indicates a serious problem which requires immediate professional assistance.


Figure 5-42 Excessive seepage near embankment toe.

Seepage varies considerably in appearance and location. Seepage may appear as a wet area, as a flowing spring, or as a sand boil as described above. Vegetation is an excellent indicator of seepage; areas with water-loving vegetation, such as cattails, reeds, and mosses, should be checked for seepage. Also, areas where the

Figure 5-43 Seepage along the spillway in this dam has resulted in piping and a serious leak.

normal vegetation appears to be greener or more lush than surrounding areas should be checked for seepage. Viewing the downstream slope from a distance is sometimes helpful in detecting subtle changes in vegetation. A distinct line of vegetation probably indicates the intersection of the seepage line with the slope.

The contacts between the downstream slope and the abutments (or groins) are especially prone to seepage because the embankment fill near the abutments is often less dense than other parts of the embankment, and therefore less watertight. The embankment fill near the abutments is less dense because compaction is difficult along the embankment and abutment interface. Also, improperly sealed porous abutment rock can introduce abutment seepage into and along the embankment. Seepage in the groins may be groundwater from the abutments or valley walls, and not seepage from the reservoir. Seepage which exhibits an orange color or oily surface sheen typically indicates the presence of dissolved iron in the water. This is a common condition of groundwater that has been in contact with iron-bearing soils. The orange coloration is from iron oxide which develops after the groundwater is exposed to the air, causing the dissolved iron to oxidize (rust) and settle out of the water. The orange coloration is from deposits of iron oxide on the ground, and is not orange water.

The embankment toe is also prone to seepage, especially at the contact with the existing ground. This area has the greatest amount water pressure and is most likely to develop seeps. Seepage often occurs along the embankment-to-foundation interface. When seepage occurs at the toe of an embankment, a slide may result. Figure 5-42 shows seepage accumulating at the toe of an embankment dam. Saturated embankment toes can cause catastrophic slope failures. Proper treatment of the foundation is crucial during the embankment construction to minimize and control seepage.


Figure 5-44 Seepage under this spillway conduit has caused piping, allowing a significant leak through conduit deficiencies.

Difficulties with soil compaction around conveyance structures like outlet works, spillway conduits, vertical walls, or penstocks make these areas more susceptible to uncontrolled seepage problems. Seepage exiting from around conveyance structures is particularly alarming because it may also indicate that there is a crack or opening in the structure that is allowing reservoir water under pressure into the embankment. Rapid erosion and an eventual breaching of the dam can result from seepage around conduits. Figure 5-43 shows serious piping along a spillway conduit. This type of seepage is excessive and will continue to erode the soils around the conduit.

Figure 5-45 Seepage along this spillway conduit has caused piping, sinkholes, and eventual erosion of all the soil over the conduit.

Seepage along and under spillway conduits can find its way into the conduits, eventually eroding and deteriorating the conduit itself, as well as removing soil and bedding material from around the conduit. The conduit may settle or collapse if sufficient soil is piped out from under the structure. This type of seepage can be best observed when reservoir levels are below the spillway crest. In this situation, water will typically be coming out of the spillway conduit but will not be entering it from the inlet of the spillway in the reservoir. Many times sediment, or deposited soils, will be visible within or at the outlet of the conduit. High reservoir water levels will aggravate this condition.

Figure 5-46 Seepage caused by tree roots through the embankment.

Another usual symptom of seepage and piping along the conduit is settlement and depressions above the conduit, particularly within the conduit trench. Again, this is the result of the removal of soil from around the conduit, allowing it to be replaced by surface soils which fall into the voids created by the piping condition.

Seepage can be caused by deep-rooted vegetation on embankments, such as trees. Tree roots can penetrate the embankment and create passageways for water. Seepage along root systems will usually start off at a very slow rate and get progressively greater with time. This is another example of the importance of early detection of seeps. As discussed earlier in this chapter, uprooted trees can also cause seepage problems.

Seepage from rock cuts on the abutments or the floor of the dam can create a number of potentially unsafe conditions. The inspector should evaluate the rate of seepage, correspondence of seepage rates to reservoir level, staining, and turbidity of seepage to fully understand the problem. Seepage can create excess hydrostatic pressure, weaken the overall strength of the abutment or foundation, and produce increasingly large channels in the soil materials for water flow. Openings can enlarge sufficiently to cause abutment or foundation movement or collapse. Stains from seepage water indicate solutioning of minerals which may reduce the shearing strength of the rock materials and cause rock consolidation. The inspector may want to take samples of the seepage so that the minerals can be identified. The inspector should also check the geologic data for evidence of deposits of limestone or other rock especially subject to solutioning that may underlie competent rock. Turbid flow indicates that internal erosion or piping is occurring. The inspector should check the construction records to see if rock walls and slopes were grouted to control seepage. If grouting was not done in the past, this procedure may control the seepage. If prior grouting proved inadequate to prevent or control seepage, a qualified dam safety professional should examine possible causes and sources for the seepage and evaluate corrective actions.


Figure 5-47 Typical photograph of seepage accumulating in low areas.

Seepage problems may accelerate exponentially after they begin, and typically get worse with time. The location, quantity, and flow rate of all seepage should be monitored at the exit points. Recent precipitation events that may affect the appearance and quantity of seepage should also be noted and recorded.

During the visual inspection, the inspector should:

- Carefully inspect all of the areas that are prone to seepage, including downstream embankment slopes, embankment toe, the area downstream of the toe, the embankment groins, and along the spillways.
- Look for all visual signs of seepage, including: wet areas, excessive vegetative growth, lush green grass, lowered reservoir pool levels, piping, boils, sinkholes, flow into the discharge conduit from the soil, flow out of the discharge conduit into the soil, and embankment slides.

If seepage is observed, the inspector should:

- Record the findings and photograph the area. Notes, sketches, and photographs are useful in documenting and evaluating seepage problems.
- Determine the extent, severity, and cause of the seepage. Measure and photograph any damage caused by the seepage so that its progression can be monitored if necessary.
- If seepage is observed, it should always be monitored and measured on a regular and frequent basis.
- The seepage should be checked for turbidity which indicates the presence of soil in the water.
- Recommend that corrective action be taken to control the seepage.
- Recommend that corrective action is taken to repair the areas damaged by seepage and that measures are taken to prevent more serious problems.

- If extensive embankment excavation is required, the reservoir level may need to be lowered.
- Consult a qualified dam safety professional if necessary.

5.10.3 Monitoring Seepage

Seepage may be or may become a serious problem and should always be monitored, regardless of the location, extent, or type of seepage present. Different monitoring procedures are available depending on the type of condition. Part 2 of the Dam Inspection Manual describes instrumentation and monitoring of seepage in more detail.

The amount of seepage usually correlates with the level of the reservoir. Generally, as the level of the reservoir rises, the seepage flow rate increases. Any changes in seepage flow rate which deviate from past seepage history are cause for concern. Recording seepage flow rates and reservoir levels will help assess a dam's seepage problems.

Seepage may discharge from the embankment at a distinct point, at several distinct points, or over a broad area. Seepage discharge at distinct points can often be readily measured. The rate of flow (gal/min, or gal/s) can be estimated and used for future comparison. The flow rate can be converted to quantity of flow over a specific period of time, such as a day, a week, or a month. These estimates can be used to determine if the embankment and/or foundation may be damaged from the flows.

Seepage on the embankment slopes, groins, or at the toe may occur over a relatively large area which does not lend itself to measurement in terms of flow rate and quantity. In these cases, the seepage may be best measured as width or length of affected area, or as a qualitative judgment of the physical appearance of the seepage area. Alternately, a dike, pipe, or other conveyance device could be installed on the embankment to concentrate the flows to facilitate measurement. If a slide has developed as is often the case, the dimensions of the slide can be measured and recorded. General descriptions of the amount of flow and degree of vegetative growth are also helpful. For example, seepage can be described as being visibly flowing on the ground surface, or as a wet spot with standing water puddles. If all of the seepage flows to a downstream channel or ditch, the flow rate may be estimated at that point.

If a **sand boil** or **piping exit** is observed, the inspector should:

- Photograph and record the size and depth of the exit, or outlet opening.
- Photograph and record the size of the deposition cone, if it is a sand boil.
- Monitor the flow rate, if possible. The flow rate may be difficult to ascertain if the pipe outlet or sand boil is under water.
- Probe the outlet opening for depth and soil composition and consistency.
- Make sure that all sand boils are evaluated by a qualified dam safety professional so that appropriate remedial action can be taken.

Sometimes placing sandbags around the boil to increase the depth of water (head) over the boil will prevent continued growth of the boil. Another temporary repair is to place a graded filter over the outlet opening to prevent additional soil from being carried out of the pipe or boil.

In some cases, a **dye test** (using an approved, environmentally safe dye) can be used to determine whether or not the reservoir is the source of seepage. A dye test is not a routine procedure, is not always applicable, and may be very difficult to administer. The approximate origin of the seep must be located in the reservoir so that the dye can be placed in the water near the area where water is entering the seep. The length of time it takes to conduct a test may vary since the dye may take different amounts of time to penetrate the embankment or foundation. In most cases, records of seepage volumes that correlate with pool elevations or comparative water sampling and testing are needed to show that seepage comes from the reservoir.

Weirs, flumes and dikes can be installed to measure seepage, especially seepage exiting from the embankment or foundation at random point sources. When properly calibrated and kept free of silt and vegetation, weirs and flumes can measure seepage accurately. These devices can also be used downstream of general seepage areas where the water flows into a ditch or channel. Weirs and flumes that are silted-in may indicate that the embankment or foundation material is being piped out of the dam, or sediment from surrounding surface runoff erosion is collecting in the structure. If weirs and flumes become silted-in, the situation should be carefully evaluated to determine the cause of the siltation. Dikes can be installed across a channel or ditch with a pipe installed to measure flow.

Many **toe drains** have collector pipes that discharge the embankment and foundation seepage at accessible locations. Before conducting a visual inspection of an embankment dam that has toe drains, the inspector should review the site plan to determine the location of the toe drains and outfalls. Previous data on both the reservoir level and flow rate from the drain(s) should be reviewed. Data on drain flow must be looked at in conjunction with reservoir-level data. Correlating the reservoir level with the drain flow can help to determine if there is a problem. If a drain flow is observed that is atypical for the given reservoir level, more investigation is essential.

Figure 5-48 Collector pipes (beside spillway conduit) can be used to help monitor seepage through the embankment.

During the visual inspection, the inspector should:

- Locate each toe drain outfall.
- Measure the flow. A simple method of measuring the flow from a toe drain outfall is to catch the flow from the pipe in a container of known volume and to time how long it takes to fill the container. The flow rate is usually recorded in gallons per minute.
- Compare the amount of flow with the amount of flow anticipated for the current reservoir level based on previous readings.

A drain that has no flow at all could indicate that there is no seepage in the area of the dam serviced by the drain, or that the drain is plugged or blocked. If the drain has never functioned, it could mean that the drain was designed or installed incorrectly. If the drain used to flow but has now stopped flowing, it may have become plugged. A plugged drain can be a serious problem because seepage may begin to exit downslope, or may contribute to internal pressure and instability. If possible, blocked drains should be cleaned so that the controlled release of seepage may be restored.

Decreasing amounts of flow from a drain for the same reservoir level may indicate that the drain is becoming blocked. Conversely, a sudden increase in drain flow may indicate that the core is becoming less watertight, possibly as the result of transverse cracking.

If **relief wells** have been installed at a dam, they may help to monitor seepage also. Before conducting a visual inspection of an embankment dam that has relief wells, the inspector should:

- Review the site plan to determine the location of the wells.
- Review previous data on both the reservoir level and well flow. Data on well flow must be evaluated in conjunction with reservoir-level data. Knowing how the reservoir level affects the well flow can help determine if there is a problem.
- If a well flow seems to be atypical for the given reservoir level, more investigation is essential.

During the visual inspection, the inspector should:

- Locate each relief well.
- Visually check whether or not water flow is occurring.
- Compare the amount of well flow measured with the amount of flow anticipated for the current reservoir level based on previous readings.

If no water is flowing from the relief well, determine if a flow should be present based on the assessment of the previous readings and the current reservoir level. If water is flowing, measure the rate of flow. The rate of flow can be measured either at the well or at the collector pipe discharge. Weirs, flumes, or a bucket and stopwatch can be used to measure the flow rate.

If the well flow is less than the amount anticipated, the well screens or filters may have become clogged. If it is suspected that the well is not functioning properly because it is clogged, cleaning should be recommended.

If the well flow is greater than the amount anticipated, there may be excessive seepage. Make sure that the flow rate and reservoir level are accurately recorded. The inspector should also note that there has been a change from the well-flow trends previously observed.

In addition to measuring the flow rate of seepage, the inspector should evaluate the clarity of the seepage. **Turbidity** is cloudy seepage, which indicates that soil particles are suspended in the water. Turbidity indicates that the water passing through the embankment or foundation is carrying soil with it. Turbidity is cause for extreme concern. Each time seepage is measured or inspected, the clarity of the seepage should also be evaluated for change.

A good way of detecting a change in turbidity is to collect a number of water samples as follows:

(1) Collect a sample of the water in a quart jar. Date the jar and note the level of clarity. Store the jar in a safe location.
(2) Repeat step 1 each time seepage flow is measured until several samples have been collected.
(3) Each time a sample is collected, shake up each jar and visually compare the new sample with the samples collected previously. Look for changes in the cloudiness of the samples. Also note the amount of sediment that accumulates in the bottom of the jars as suspended material settles out.

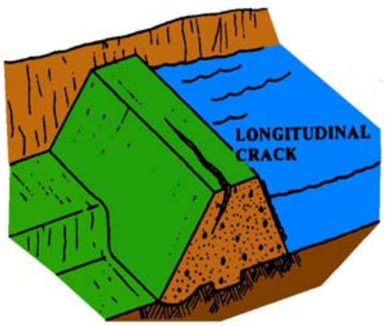
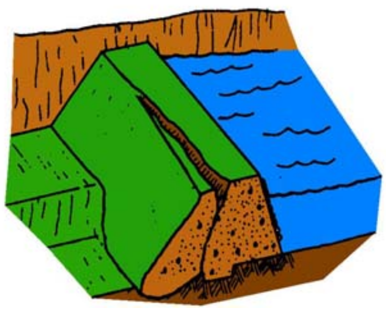
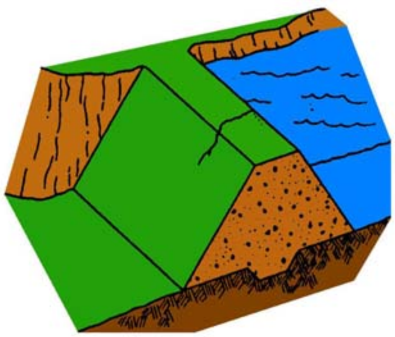
If seepage is clear, but it is suspected that it contains dissolved material from the foundation (because, for instance, seepage has increased without any signs of turbidity), it may be necessary to perform water quality testing.

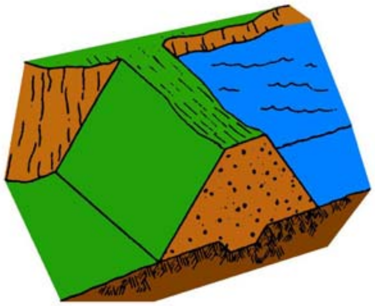
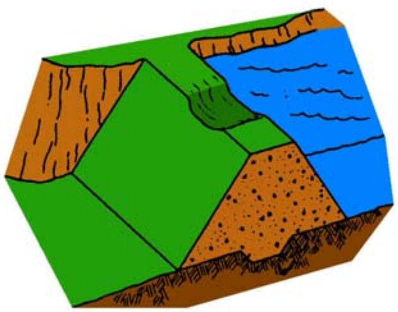
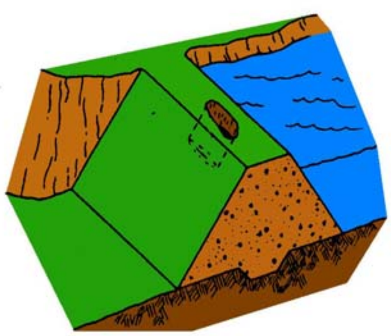
The rate and turbidity of seepage flow should be recorded during each visual inspection. If seepage problems are suspected, then the frequency of inspections should be determined by a qualified dam safety professional. If seepage problems continue to occur, further testing should be conducted by a qualified dam safety professional. Seepage problems are a serious concern, and uncontrolled seepage is a major cause of embankment dam failure.

Piezometers or monitoring wells can be installed in the embankment to monitor the level of water in the soil. These wells can be useful for detecting changes in seepage within the embankment, and for detecting excessive seepage zones if they are installed at intervals across the entire length of the embankment. The level to which water will rise in a piezometer is equal to the pressure at that location. If there is no seepage present, there will be no water observed in the piezometer well. They can also be installed in the foundation and abutments to monitor groundwater. Installation of piezometers requires a qualified geotechnical contractor. Piezometer monitoring is generally not as effective as seepage monitoring since piezometers only measure conditions at the exact location at which they are installed.

5.11 Dam Inspection Sketches

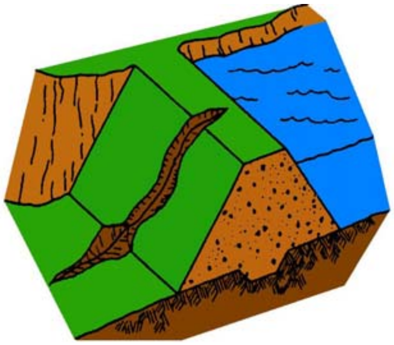
The following pages contain sketches of conditions that may be found on the embankment of the dam during a visual inspection. While most of the conditions on the following tables can be corrected by routine and periodic maintenance conducted by the owner, some of the conditions noted are of a nature that threaten the safety and integrity of the dam and require the attention of a qualified dam safety professional (if immediate emergency action is not required). A qualified dam safety professional is a person with specific expertise in the field of concern. For example, an engineer or geologist with geotechnical or geological experience may need to be consulted if a slope stability or soil issue exists. Or, an engineer with hydrologic and hydraulic experience may need to be consulted to determine spillway capacity. Depending on the severity of the condition, the dam owner may need to take immediate action to prevent the condition from worsening, including contacting repair contractors, notifying local emergency authorities, and notifying downstream residents or occupants.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
LONGITUDINAL CRACKING  	**Probable Cause:** 1. Uneven settlement between adjacent sections or zones within the embankment. 2. Foundation failure causing loss of support to embankment. **Harm**: 1. Creates local area of low strength within embankment. Could be the point of initiation of future structural movement, deformation, or failure. 2 Provides entrance point for surface run-off into embankment, allowing saturation of adjacent embankment area and possible lubrication which could lead to localized failure.	**Potential Action:** 1. Inspect crack and carefully record location, length, depth, width, alignment, and other pertinent physical features. Immediately stake out limits of cracking. Monitor frequently. 2. Engineer should determine cause of cracking and supervise steps necessary to reduce danger of dam and correct condition. 3. Effectively seal the cracks at the crest's surface to prevent infiltration by surface water. 4. Continue to routinely monitor crest for evidence of further cracking. *Qualified Dam Safety Professional Required*
VERTICAL DISPLACEMENT 	**Probable Cause:** 1. Vertical movement between adjacent sections of the embankment. 2. Structural deformation or failure caused by structural stress or instability, or by failure of the foundation. **Harm**: 1. Provides local area of low strength within embankment which could cause future movement. 2. Leads to structural instability or failure. 3. Provides entrance point for surface water that could further lubricate failure plane. 4. Reduces available embankment cross section.	**Potential Action:** 1. Carefully inspect displacement and record its location, vertical and horizontal displacement, length, and other physical features. Immediately stake out limits of cracking. 2. Engineer should determine cause of displacement and supervise all steps necessary to reduce danger to dam and correct condition. 3. Excavate area to the bottom of the displacement. Backfill excavation, using competent material and correct construction techniques, under supervision of engineer. 4. Continue to monitor areas routinely for evidence of future cracking or movement. *Qualified Dam Safety Professional Required*
TRANSVERSE CRACKING 	**Probable Cause:** 1. Uneven movement between adjacent segments of the embankment. 2. Deformation caused by structural stress or instability. **Harm**: 1. Can provide a path for seepage through the embankment cross section. 2. Provides local area of low strength within embankment. Future structural movement, deformation, or failure could begin at this point. 3. Provides entrance point for surface run-off to enter embankment.	**Potential Action:** 1. Inspect crack and carefully record crack location, length, depth, width, and other pertinent physical features. Stake out limits of cracking. 2. Engineer should determine cause of cracking and supervise all steps necessary to reduce danger to dam and correct condition. 3. Excavate crest along crack to a point below the bottom of the crack. Then backfill excavation using competent material and correct construction techniques. This will seal the crack against seepage and surface run-off. This should be supervised by engineer. 4. Continue to monitor crest routinely for evidence of future cracking. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
CREST ALIGNMENT 	**Probable Cause**: 1. Movement between adjacent portions of the structure. 2. Uneven deflection of dam under loading by reservoir. 3. Structural deformation or failure near area of misalignment. **Harm**: 1. Area of misalignment is usually accompanied by low area in crest which reduces free board. 2. Can produce local areas of low embankment strength which may lead to failure.	**Potential Action:** 1. Establish monuments across crest to determine exact amount, location, and extent of misalignment. 2. Engineer should determine cause of misalignment and supervise all steps necessary to reduce threat to dam and correct condition. 3. Monitor crest monuments on a schedule basis following remedial action to detect possible future movement. *Qualified Dam Safety Professional Required*
LOW AREA IN CREST OF DAM 	**Probable Cause**: 1. Excessive settlement in the embankment or foundation directly beneath the low area in the crest. 2. Internal erosion of embankment material. 3. Foundation spreading toward upstream and/or downstream direction. 4. Prolonged wind erosion of crest area. 5. Improper final grading following construction. **Harm**: Reduces freeboard available to pass flood flows safely through spillway.	**Potential Action:** 1. Establish monuments along length of crest to determine exact amount, location, and extent of settlement in crest. 2. Engineer should determine cause of low area and supervise all steps necessary to reduce possible threat to the dam and correct condition. 3. Re-establish uniform crest elevation over crest length by placing fill in low area using proper construction techniques. This should be supervised by engineer. 4. Re-establish monuments across crest of dam and monitor monuments on a routine basis to detect possible future settlement. *Qualified Dam Safety Professional Required*
SINKHOLE IN CREST 	**Probable Cause**: 1. Rodent activity. 2. Hole in outlet conduit is causing erosion of embankment material. 3. Internal erosion or piping of embankment material by seepage. 4. Breakdown of dispersive clays within embankment by seepage waters. **Harm**: 1. Void within dam could cause localized caving, sloughing, instability, or reduced embankment cross section. 2. Entrance point for surface water.	**Potential Action**: 1. Carefully inspect and record location and physical characteristics (depth, width, length) of sinkhole. 2. Engineer should determine cause of sinkhole and supervise all steps necessary to reduce threat to dam and correct condition. 3. Excavate sinkhole, slope sides of excavation, and backfill hole with competent material using proper construction techniques. This should be supervised by an engineer. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

GULLY ON CREST



Probable Cause:

1. Poor grading and improper drainage of crest. Improper drainage causes surface run-off to collect and drain off crest at low point in upstream or downstream shoulder.
2. Inadequate spillway capacity which has caused dam to overtop.

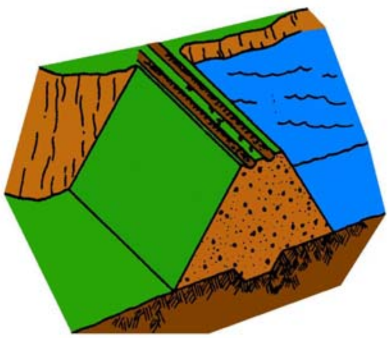
Harm:

1. Can reduce available freeboard.
2. Reduces cross-sectional area of dam.
3. Inhibits access to all parts of the crest and dam.

Potential Action:

1. Restore freeboard to dam by adding fill material in low area, using proper construction techniques.
2. Re-grade crest to provide proper drainage of surface run-off.
3. If gully was caused by over-topping, provide adequate spillway which meets current design standards. This should be done by engineer.
4. Re-establish protective cover.

RUTS ALONG CREST



Probable Cause:

Heavy vehicular traffic without adequate or proper maintenance or proper crest surfacing.

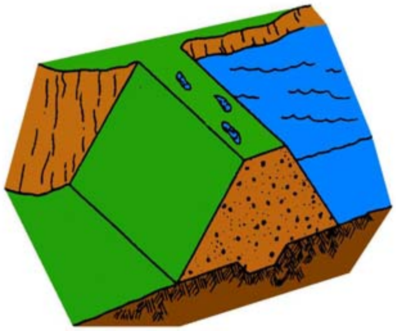
Harm:

1. Inhibits easy access to all parts of crest.
2. Allows continued development of rutting.
3. Allows standing water to collect and saturate crest of dam.
4. Operating and maintenance vehicles can get stuck.

Potential Action:

1. Drain standing water from ruts.
2. Re-grade and re-compact crest to restore integrity and provide proper drainage toward upstream slope.
3. Provide gravel or road base material to accommodate traffic.
4. Perform periodic maintenance and re-grading to prevent reformation of ruts.

PUDDLING ON CREST; POOR DRAINAGE



Probable Cause:

1. Poor grading and improper drainage of crest.
2. Localized consolidation or settlement on crest allows puddles to develop.

Harm:

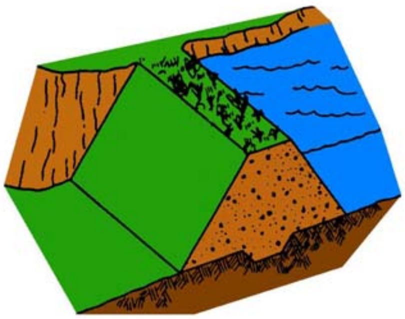
1. Causes localized saturation of the crest.
2. Inhibits access to all portions of the dam and crest.
3. Becomes progressively worse if not corrected.

Potential Action:

1. Drain standing water from puddles.
2. Re-grade and re-compact crest to restore integrity and provide proper drainage toward upstream slope.
3. Provide gravel or road base material to accommodate traffic.
4. Perform periodic maintenance and re-grading to prevent reformation of ruts.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

OBSCURING VEGETATION



Probable Cause:

Neglect of dam and lack of proper maintenance procedures.

Harm:

1. Obscures large portions of the dam, preventing adequate, accurate visual inspection of all portions of the dam. Problems that threaten the integrity of the dam can develop and remain undetected until they progress to a point where the dam's safety is threatened.

2. Associated root systems develop and penetrate into the dam's cross section. When the vegetation dies, the decaying root systems can provide paths for seepage. This reduces the effective seepage path through the embankment and could lead to possible piping situations.

3. Prevents easy access to all portions of the dam for operation, maintenance, and inspection.

4. Provides habitat for rodents.

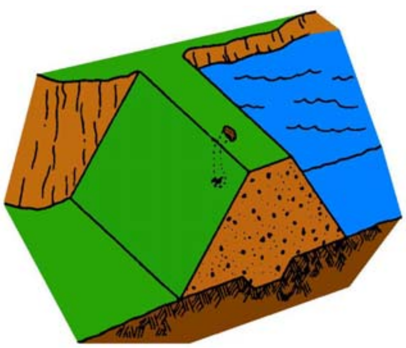
Potential Action:

1. Remove all detrimental growth from the dam. This would include removal of trees, bushes, brush, conifers, and growth other than grass. Grass should be encouraged on all segments of the dam to prevent erosion by surface run-off. Root systems should also be removed to the maximum practical extent. The void which results from removing the root system should be backfilled with competent, well-compacted material.

2. Future undesirable growth should be removed by cutting or spraying, as part of an annual maintenance program.

3. All cuttings or debris resulting from the vegetative removal should be immediately taken from the dam and properly disposed of outside the reservoir basin.

RODENT ACTIVITY ON CREST



Probable Cause:

Burrowing animals.

Harm:

1. Entrance point for surface runoff to enter dam. Could saturate adjacent portions of the dam.

2. Especially dangerous if hole penetrates dam below phreatic line. During periods of high storage, seepage path through the dam would be greatly reduced and a piping situation could develop.

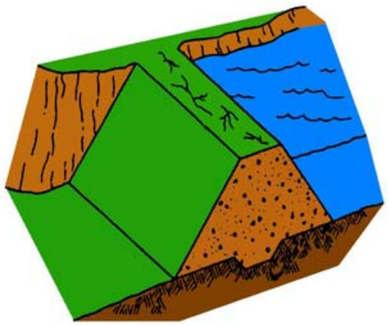
Potential Action:

1. Completely backfill the hole with competent, well compacted material.

2. Initiate a rodent control program to prevent the propagation of the burrowing animal population and to prevent future damage to the dam.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

DRYING CRACKS



Probable Cause:

Material on the crest of dam expands and contracts with alternate wetting and drying of weather cycles. Drying cracks are usually short, shallow, narrow, and numerous.

Harm:

Provides point of entrance for surface run-off and surface moisture, causing saturation of adjacent embankment areas. This saturation and subsequent drying of the dam could cause further cracking.

Potential Action:

1. Seal surface of cracks with a tight, impervious material.

or…

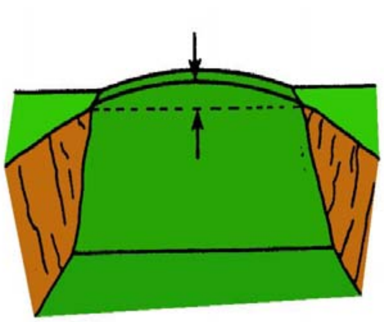
2. Routinely grade crest to provide proper drainage and till cracks.

or…

3. Cover crest with non-plastic (not clay) material to prevent large moisture content variations with respect to time.

4. Draw the reservoir down if safety of dam is threatened.

CREST CAMBER



Probable Cause:

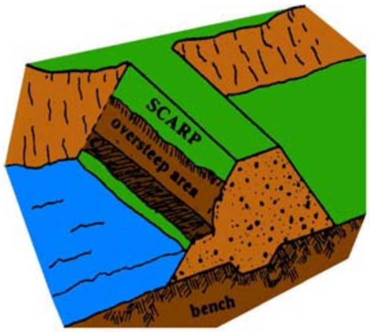
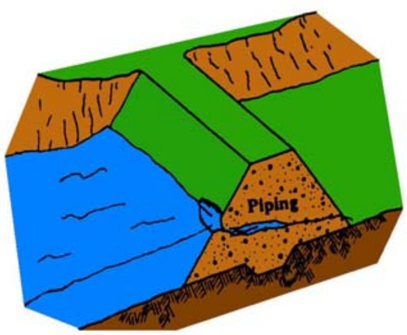
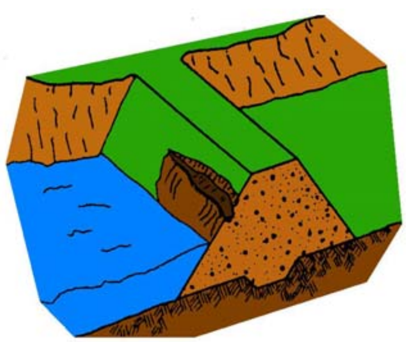
Results from construction. Proportionally more fill is placed on crest in higher segments of the embankment during construction to compensate for anticipated settlement within the dam and foundation.

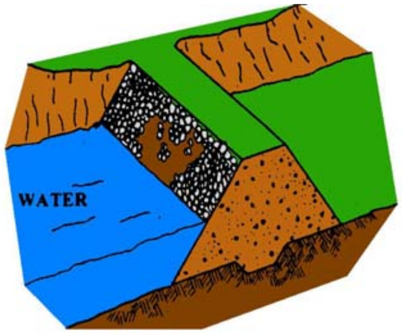
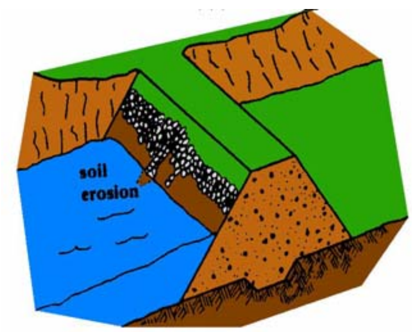
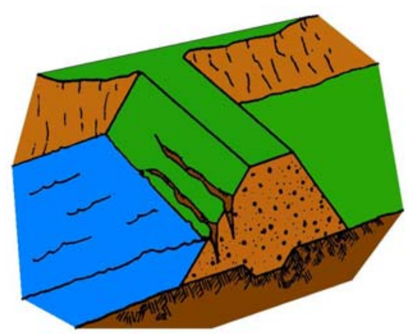
Harm:

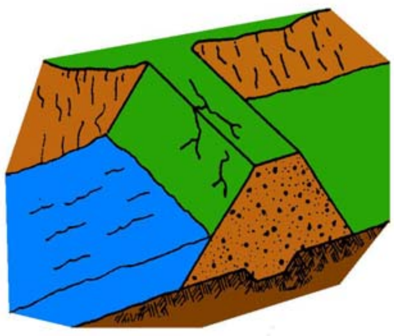
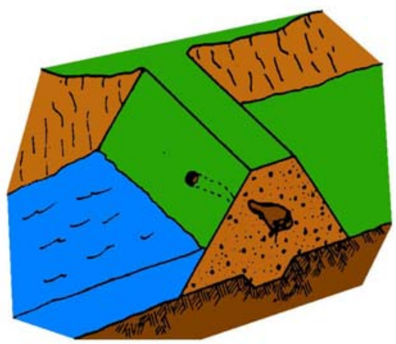
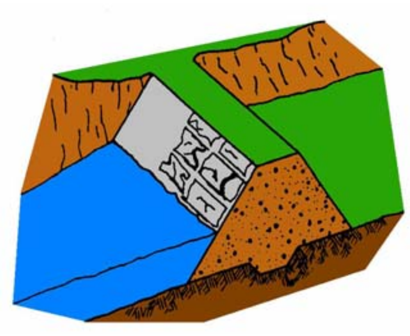
None.

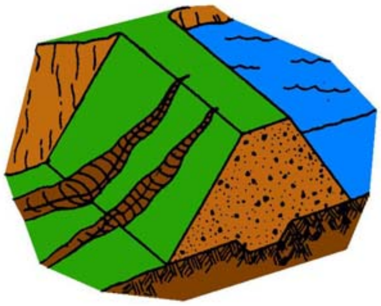
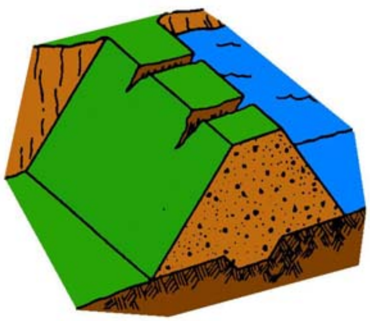
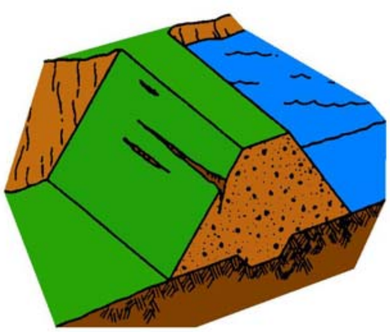
Potential Action:

None.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
SCARPS, BENCHES, OVERSTEEP AREAS 	**Probable Cause**: Wave action, local settlement, or ice action cause soil and rock to erode and slide to the lower part of the slope forming a bench. **Harm**: This eroded area lessens the width and possible height of the embankment and could lead to increased seepage or overtopping of the dam.	**Potential Action**: Determine exact cause of scarps. Do necessary earthwork, restore embankment to original slope, provide adequate protection (bedding and riprap).
SINKHOLE 	**Probable Cause**: The piping of embankment material or foundation material causes a sink hole. The cave-in of an eroded cavern can result in a sink hole. A small hole in the wall of an outlet pipe can develop a sink hole. **Harm**: This condition can empty a reservoir through a small hole in the wall of an outlet pipe or can lead to failure of a dam as soil pipes through the foundation or a pervious portion of the dam.	**Potential Action**: Inspect other portions of the dam for seepage or additional sink holes. Identify exact cause of sink holes. Check seepage and leakage outflows for dirty water. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
SLIDE, SLUMP, OR SLIP 	**Probable Cause**: Earth or rocks move down the slope along a slippage surface because they were on too steep a slope, or the foundation moves. Also, look for slides in reservoir basin. **Harm**: A series of slides can lead to obstruction of the outlet or failure of the dam.	**Potential Action**: Evaluate extent of the slide. Monitor slide. Draw the reservoir level down if safety of dam is threatened. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
BROKEN DOWN, MISSING RIPRAP 	**Probable Cause**: Poor quality riprap has deteriorated. Wave action or ice action has displaced riprap. Round and similar sized rocks have rolled downhill. **Harm**: Wave action against these unprotected areas decreases embankment width.	**Potential Action**: Re-establish normal slope. Place bedding and competent riprap.
EROSION BEHIND POORLY GRADED RIPRAP 	**Probable Cause**: Similar-sized rocks allow waves to pass between them and erode small gravel particles and soil. **Harm**: Soil is eroded away from behind the riprap. This allows riprap to settle, providing less protection and decreased embankment width.	**Potential Action**: Re-establish effective slope protection. Place bedding material. ENGINEER REQUIRED for design of gradation and size of rock for bed-ding and riprap. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
LARGE CRACKS ON SLOPE 	**Probable Cause**: A portion of the embankment has moved due to loss of strength, or the foundation may have moved, causing embankment movement. **Harm**: Can lead to failure of the dam.	**Potential Action**: Depending on the amount of embankment involved, draw reservoir level down. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
CRACKS DUE TO DRYING 	**Probable Cause**: The soil loses its moisture and shrinks, causing cracks. Note: Usually seen on crest and downstream slope mostly. **Harm**: Heavy rains can fill up cracks and cause small portions of embankment to move along internal slip surface.	**Potential Action**: 1. Monitor cracks for increases in width, depth, or length. 2. A qualified engineer should inspect the condition and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
BEAVER OR MUSKRAT ACTIVITY 	**Probable Cause**: Holes, tunnels, and caverns are caused by animal burrows. Certain habitats like cattail-type plants and trees close to the reservoir encourage these animals. **Harm**: If a tunnel exists through most of the dam, it can lead to failure of the dam.	**Potential Action**: Remove rodents. Determine exact location of digging and extent of tunneling. Remove habitat. Repair damages.
CRACKED DETERIORATED CONCRETE FACE 	**Probable Cause**: Concrete deteriorated due to weathering. Joint filler deteriorated or displaced. **Harm**: Soil is eroded behind the face and caverns can be formed. Unsupported sections of concrete crack. Ice action may displace concrete.	**Potential Action**: 1. Determine cause. Either patch with grout or contact engineer for permanent repair method. 2. If damage is extensive, a qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
EROSION 	**Probable Cause**: Water from intense rainstorms or snow-melt carries surface material down the slope, resulting in continuous troughs. **Harm**: If allowed to continue, erosion can lead to eventual deterioration of the downstream slope which can shorten the seepage path.	**Potential Action**: 1. The preferred method to protect eroded areas is rock or riprap. 2. Re-establishing protective grasses can be adequate if the problem is detected early.
TRANSVERSE CRACKING AFFECTING SLOPE 	**Probable Cause**: 1. Drying and shrinkage of surface material is most common. 2. Differential settlement of the embankment also leads to transverse cracking (e.g., center settles more than abutments). **Harm**: 1. Shrinkage cracks allow water to enter the embankment. This promotes saturation and increases freeze thaw action. 2. Settlement cracks can lead to seepage of reservoir water through the dam. 3. Can lead to uncontrolled breach.	**Potential Action**: 1. If necessary plug upstream end of crack to prevent flows from the reservoir. 2. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
LONGITUDINAL CRACKING ON SLOPE 	**Probable Cause**: 1. Drying and shrinkage of surface material. 2. Downstream movement or settlement of embankment. **Harm**: 1. Can be an early warning of a potential slide. 2. Shrinkage cracks allow water to enter the embankment and freezing will further crack the embankment. 3. Settlement or slide indicating loss of strength in embankment can lead to failure.	**Potential Action**: 1. If cracks are from drying, dress area with well-compacted material to keep surface water out and natural moisture in. 2. If cracks are extensive, a qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

SLIDE/SLOUGH

Probable Cause:

1. Lack of or loss of strength of embankment material.

2. Loss of strength can be attributed to infiltration of water into the embankment or loss of support by the foundation.

Harm:
Can lead to failure of the dam.

Potential Action:

HAZARDOUS!

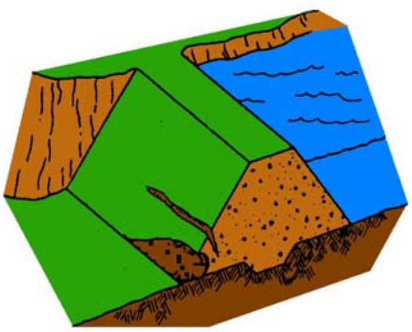
1. Measure extent and displacement of slide.

2. If continued movement is seen, begin lowering water level until movement stops.

3. Have a qualified engineer inspect the condition and recommend further action.

Qualified Dam Safety Professional Required

SLUMP (LOCALIZED CONDITION0



Probable Cause:

Preceded by erosion undercutting a portion of the slope. Can also be found on relatively steep slopes.

Harm:

Can expose impervious zone to erosion.

Potential Action:

1. Inspect area for seepage.

2. Monitor for progressive failure.

3. Have a qualified engineer inspect the condition and recommend further action.

Qualified Dam Safety Professional Required

SINK HOLE/COLLAPSE

Probable Cause:

Lack of adequate compaction; rodent hole below; piping through embankment or foundation.

Harm:

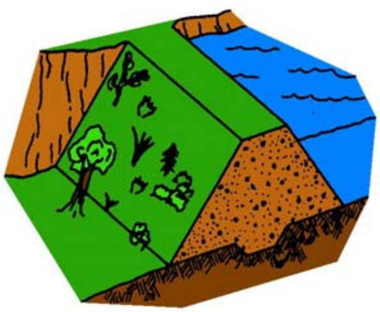
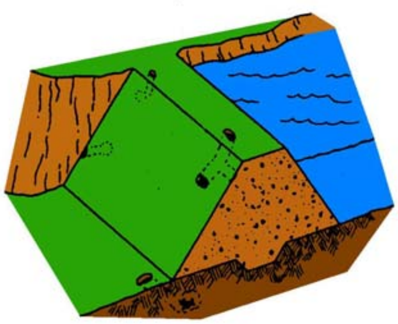
Shortens seepage path, can lead to washout of embankment and uncontrolled breach.

Potential Action:

1. Inspect for and immediately repair rodent holes. Control rodents to prevent future damage.

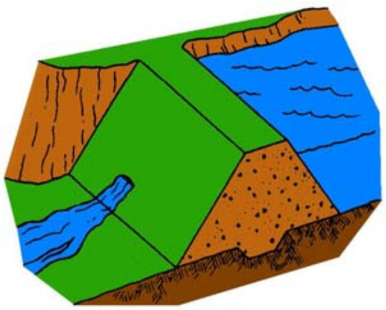
2. Have a qualified engineer inspect the condition and recommend further action.

Qualified Dam Safety Professional Required

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
TREES/OBSCURING BRUSH 	**Probable Cause**: Natural vegetation in area. **Harm**: Large tree roots can create seepage paths. Brush can obscure visual inspection and harbor rodents.	**Potential Action**: 1. Remove all large, deep-rooted trees and shrubs on or near the embankment. Properly backfill void. 2. Control all other vegetation on the embankment that obscures visual inspection.
RODENT ACTIVITY ON SLOPE 	**Probable Cause**: Overabundance of rodents. **Harm**: Reduces length of seepage path. Can lead to piping failure.	**Potential Action**: 1. Control rodents to prevent additional damage. 2. Backfill existing rodent holes.
LIVESTOCK/CATTLE TRAFFIC 	**Probable Cause**: Excessive travel by livestock especially harmful to slope when wet. **Harm**: Creates areas bare of erosion protection and causes erosion channels. Allows water to stand. Area susceptible to drying cracks.	**Potential Action**: 1. Fence livestock outside embankment area. 2. Repair erosion protection, i.e., riprap, grass.

PROBLEMS | **CAUSES & HARM DONE** | **ACTION REQUIRED**

MUDDY WATER EXITING FROM A POINT SOURCE



Probable Cause:

1. Water has created an open pathway, channel, or pipe through the dam. The water is eroding and carrying embankment material.

2. Large amounts of water have accumulated in the downstream slope. Water and embankment materials are exiting at one point. Surface agitation may be causing the muddy water.

Harm:

Continued flows can further erode embankment materials. This can lead to failure of the dam.

Potential Action:

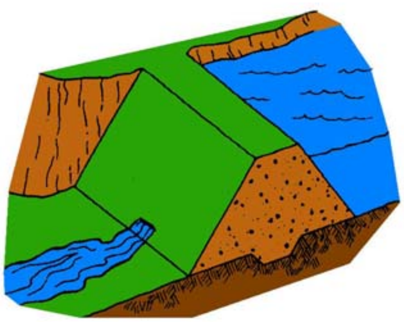
1. Begin measuring outflow quantity and establishing whether water is getting muddier, staying the same, or clearing up.

2. If quantity of flow is increasing, the water level in the reservoir should be lowered until the flow stabilizes or stops.

3. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

WATER EXITING FROM A POINT SOURCE



Probable Cause:

Water has created an open pathway or pipe through the dam.

Harm:

Continued flows can further erode embankment materials. This can lead to failure of the dam.

Potential Action:

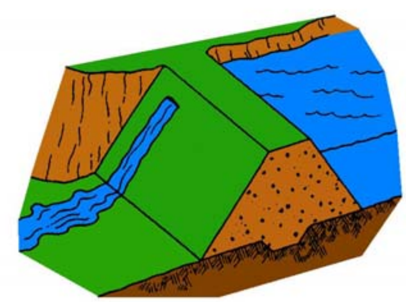
1. Begin measuring outflow quantity.

2. If quantity of flow is increasing, the water level in the reservoir should be lowered until the flow stabilizes or stops.

3. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

WATER EXITING FROM A POINT SOURCE HIGH ON THE EMBANKMENT



Probable Cause:

1. Rodents, frost action, or poor construction have allowed water to create an open pathway or pipe through the embankment.

Harm:

1. Continued flows can saturate portions of the embankment and lead to slides in the area.
2. Continued flows can further erode embankment materials and lead to failure of the dam.

Potential Action:

1. Begin measuring outflow quantity.

2. If quantity of flow is increasing, the water level in the reservoir needs to be lowered until the leak stops.

3. Search for opening on upstream side and plug it if possible.

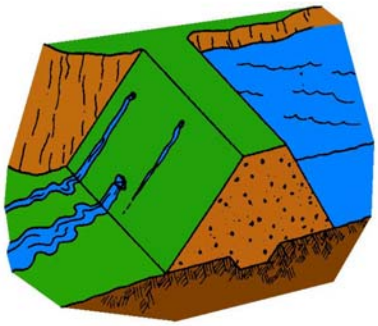
4. A qualified engineer should immediately inspect the condition and recommend further action to be taken.

Qualified Dam Safety Professional Required

All problems are potentially hazardous.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

WATER EXITING FROM RODENT HOLES



Probable Cause:

Diggings by the rodent have shortened the flow path.

Harm:

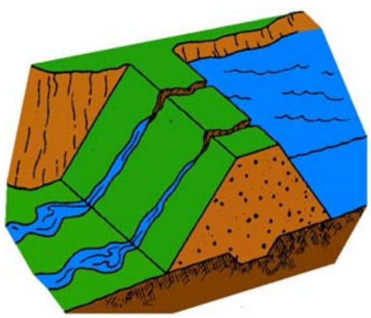
Continued flows can further erode embankment material and lead to failure of the dam.

Potential Action:

1. Locate any entrance points on the upstream slope and plug them.
2. If the quantity of flow is increasing, the water level in the reservoir needs to be lowered until the leak stops.
3. Bring a halt to the rodent activity.
4. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

STREAM OF WATER EXITING THROUGH CRACKS NEAR THE CREST



Probable Cause:

1. Severe drying has caused shrinkage of embankment material.
2. Settlement in the embankment or foundation is causing the transverse cracks.

Harm:

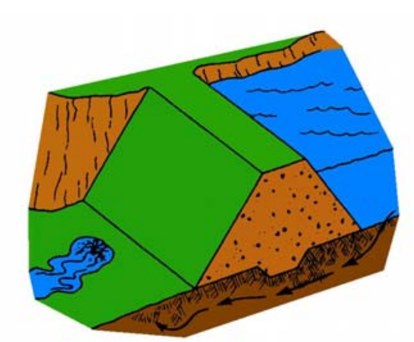
Flow through the crack can cause failure of the dam.

Potential Action:

1. Plug the upstream side of the crack to stop the flow.
2. The water level in the reservoir should be lowered until it is below the level of the cracks.
3. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

SEEPAGE WATER EXITING AS A BOIL IN THE FOUNDATION



Probable Cause:

Some portion of the foundation material is providing a flow path. This could be caused by a sand or gravel layer in the foundation.

Harm:

Increased flows can lead to erosion of the foundation and failure of the dam.

Potential Action:

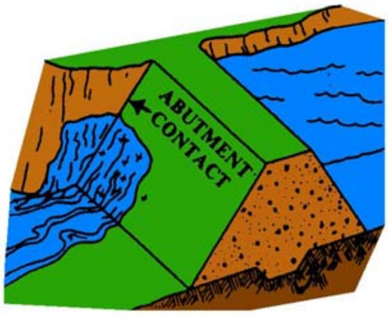
1. Examine the boil for transportation of foundation materials.
2. If soil particles are moving downstream, sandbags or earth should be used to create a dike around the boil. The pressure created by the water level within the dike may control flow velocities and temporarily prevent further erosion. A graded filter may also be placed in the boil to inhibit soil loss.
3. If erosion is becoming greater, the reservoir level should be lowered.
4. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

All problems are potentially hazardous.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

SEEPAGE EXITING AT ABUTMENT CONTACT



Probable Cause:

1. Water flowing through pathways in the abutment.

2. Water flowing through the embankment.

Harm:

Can lead to erosion of embankment materials and failure of the dam.

Potential Action:

1. Investigate leakage area to determine quantity of flow and extent of saturation.

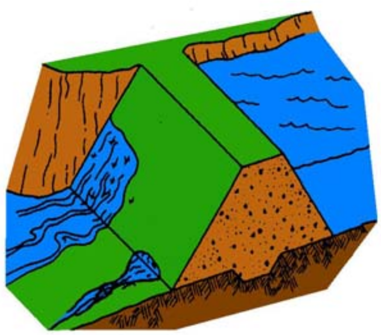
2. Inspect daily for developing slides.

3. Water level in reservoir may need to be lowered to assure the safety of the embankment.

4. A qualified engineer should inspect the conditions and recommend further actions to be taken.

Qualified Dam Safety Professional Required

LARGE AREA WET OR PRODUCING FLOW



Probable Cause:

A seepage path has developed through the abutment or embankment.

Harm:

1. Increased flows could lead to erosion of embankment material and failure of the dam.

2. Saturation of the embankment can lead to local slides which could cause failure of the dam.

Potential Action:

1. Stake out the saturated area and monitor for growth or shrinking.

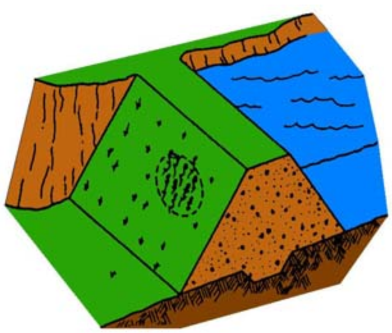
2. Measure any outflows as accurately as possible.

3. Reservoir level may need to be lowered if saturated areas increase in size at a fixed storage level or if flow increases.

4. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

MARKED CHANGED IN VEGETATION



Probable Cause:

1. Embankment materials are providing flow paths.

2. Natural seeding by wind.

3. Change in seed type during initial post construction seeding.

Harm:

Can indicate a saturated area.

Potential Action:

1. Use probe or shovel to establish if the materials in this area are wetter than in surrounding areas.

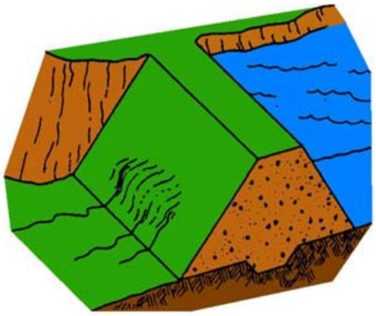
2. If area shows wetness when surrounding areas do not, a qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

All problems are potentially hazardous.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

BULGE IN LARGE WET AREA



Probable Cause:

Downstream embankment materials have begun to move.

Harm:

Failure of the embankment due to massive sliding can follow these initial movements.

Potential Action:

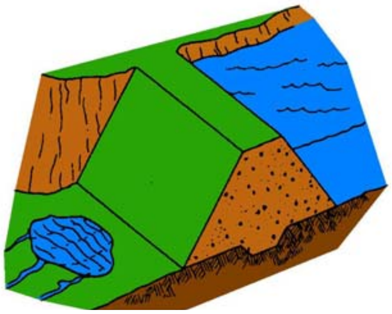
1. Compare embankment cross-section to the end of construction condition to see if observed condition may reflect end of construction.

2. Stake out affected area and accurately measure outflow.

3. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

TRAMPOLINE EFFECT IN LARGE SOGGY AREA



Probable Cause:

Water moving rapidly through the embankment or foundation is being controlled or contained by a well-established turf root system.

Harm:

Condition indicates excessive seepage in the area. If control layer of turf is destroyed, rapid erosion of foundation materials could result in failure of the dam.

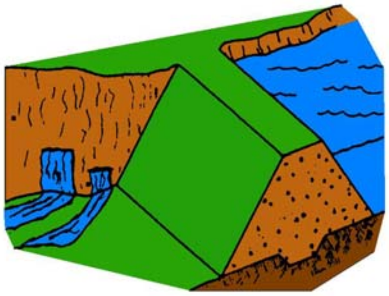
Potential Action:

1. Carefully inspect the area for outflow quantity and any transported materials.

2. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

LEAKAGE FROM ABUTMENTS BEYOND THE DAM



Probable Cause:

Water moving through cracks and fissures in the abutment materials.

Harm:

1. Can lead to rapid erosion of abutment and evacuation of the reservoir.

2. Can lead to massive slides near or downstream from the dam.

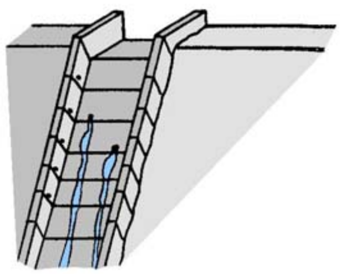
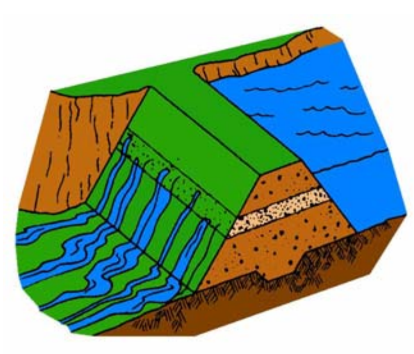
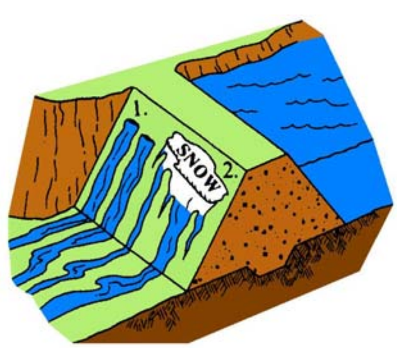
Potential Action:

1. Carefully inspect the area to determine quantity of flow and amount of transported material.

2. A qualified engineer or geologist should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

All problems are potentially hazardous.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
TOO MUCH LEAKAGE FROM SPILLWAY UNDER DRAINS 	**Probable Cause**: Drain or cutoff may have failed. **Harm**: 1. Excessive flows under the spillway could lead to erosion of foundation material and collapse of portions of the spillway. 2. Uncontrolled flows could lead to loss of stored water.	**Potential Action**: 1. Immediately measure flow quantity and check flows for transported drain material. 2. If flows are accelerating at a fixed storage level, the reservoir level should be lowered until the flow stabilizes or stops. 3. A qualified engineer should inspect the condition and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
WET AREA IN HORIZONTAL BAND 	**Probable Cause**: Frost layer or layer of sandy material in original construction. **Harm**: 1. Wetting of areas below the area of excessive seepage can lead to localized instability of the embankment. (SLIDES) 2. Excessive flows can lead to accelerated erosion of embankment materials and failure of the dam.	**Potential Action**: 1. Determine as closely as possible the amount of flow being produced. 2. If flow increases, reservoir level should be reduced until flow stabilizes or stops. 3. Stake out the exact area involved. 4. Using hand tools, try to identify the material allowing the flow. 5. A qualified engineer should inspect the condition and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
LARGE AREA SATURATED FROM ABOVE 	**Probable Cause**: 1. Water flowing through the embankment. 2. Snowdrifts melting slowly during mild spring temperatures. **Harm**: Can lead to saturation of embankment materials and local or massive slides which could cause failure of the dam.	**Potential Action**: 1. Investigate saturated area to determine depth and extent of saturation. 2. Inspect daily for developing slides. 3. Water level in reservoir may need to be lowered to assure the safety of the embankment. 4. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*

All problems are potentially hazardous.

CHAPTER 6.0

INSPECTION OF SPILLWAYS AND OUTLETS

6.0 INSPECTION OF SPILLWAYS AND OUTLETS

6.1 INTRODUCTION

The purpose of a dam safety inspection is to identify deficiencies that potentially affect the safety of the dam. An inspector should develop a methodical procedure for visually inspecting a dam to ensure that all features and areas are examined and to minimize the amount of time spent in the field. This chapter focuses on the visual inspection of dam spillways and outlet structures. These structures are part of the appurtenant works of embankment and concrete dams.

Figure 6-1 Principal spillway utilizing a riser as the control; this is the most common type of spillway in Indiana. The riser has a trash rack over the top constructed with concrete and steel bars.

The purpose of this chapter is to help dam owners and inspectors identify common problems that affect the performance of spillways and outlets in dams, and outline visual inspection procedures. The general technique for visually inspecting spillways and outlets is to examine each feature closely from a short distance to see the entire structure clearly. All visible defects should be identified, measured, evaluated, and recorded. Some form of report or documentation with recommendations for corrective action is then prepared for the owner's project files. Some spillways and outlets may be difficult to access and may require special equipment to complete the visual inspection.

The spillway system consists of the structures over or through which base inflows and flood flows are safely discharged. If the flow is controlled by gates, it is a **controlled spillway**; if the elevation of the spillway crest is the only control, it is an **uncontrolled spillway**. Uncontrolled spillways are the most commonly used type in Indiana. Figure 6-1 shows an uncontrolled spillway; the control section is the crest of a riser pipe.

The inspector should review the owner's project files for design capacity calculations to make sure that the dam spillway system can safely handle the design storm event. The inspector should also look for signs of high water level when he/she is performing the visual inspection.

Spillways typically include all or most of the following four components, each serving a different function: (1) entrance channel, (2) control section, (3) outlet channel, and (4) terminal structure. The **entrance channel** conveys water from the reservoir to the control section and is usually required except for drop inlet spillways located in the reservoir and overflow spillways on concrete dams. The **control section** governs the spillway discharge. Control sections may be orifice-like openings, conduit entrances, or a crest in the form of a shaped weir or a sill. They may be either unregulated or regulated by gates, flashboards, and valves. The **outlet channel** conveys and returns the water to the stream beyond the dam or into other topographic depressions beyond the reservoir basin. The channel may be on the face of a concrete dam; an open channel, lined or unlined, in natural formations; a conduit through or beneath the dam; or a tunnel through an abutment. Free falling flows from overpouring crests require no outlet channel. The outlet channel should be positioned so that it does not erode the embankment and foundation. The inspector should be on the lookout for outlet channels that discharge near the embankment toe. The **terminal structure** prevents excessive erosion of the stream channel or damage to adjacent structures and the dam from the high-energy spillway discharges. Stilling basins, roller buckets, baffled impact-type basins, and lined aprons are commonly used as terminal structures.

Spillway systems typically consist of a **principal spillway** and an **auxiliary spillway** (often referred to as an **emergency spillway**). The principal spillway is the first-used spillway during base inflow and flood flows. The auxiliary spillway is a secondary spillway designed to operate in conjunction with the principal spillway; when used, the principal spillway is designed to pass floods likely to occur frequently, and the auxiliary spillway is set to operate only after such small floods are exceeded. The combination of the principal and auxiliary (or emergency) spillway should safely pass the design storm event without overtopping the unprotected portion of the embankment.

The following types of spillways are commonly found at dams; however, many variations of these spillways may be used. Figure 6-2 illustrates some commonly used types of spillways. The most commonly used spillways used in Indiana include the drop inlet (or shaft) spillway used as the principal spillway, and an open channel used as the principal spillway or as an auxiliary, or emergency spillway.

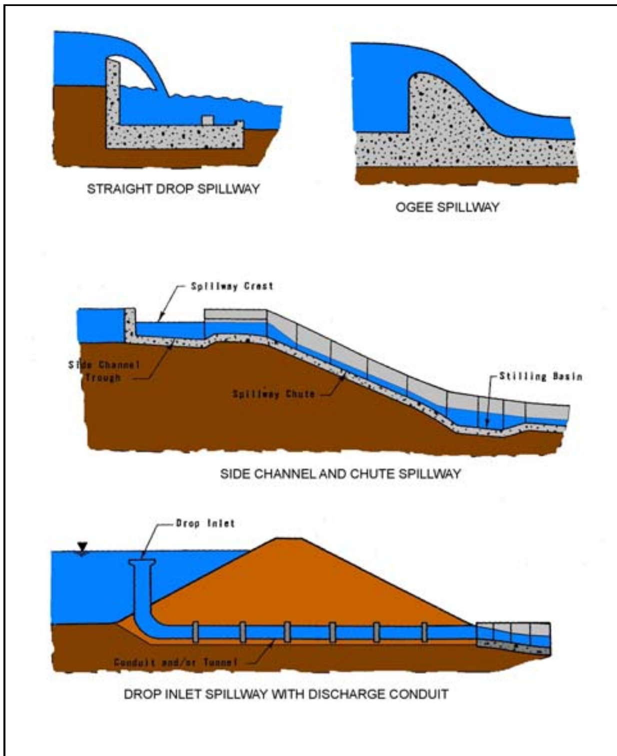


Figure 6-2 Commonly used types of spillways.

Drop Inlet Spillway (also called Morning Glory Spillway, or Shaft Spillway) - A vertical or inclined shaft into which flood water spills and then is conducted through, under, or around a dam by means of a conduit or tunnel. If the upper part of the shaft is splayed out and terminates in a circular horizontal weir, it is termed a "bellmouth" or "morning glory" spillway. The vertical portion of the spillway is called the **riser**. The risers are typically reinforced concrete pipes or boxes. Shaft spillways are commonly used in Indiana as the principal spillway, and are usually referred to as drop inlets or risers.

Side Channel Spillway - A spillway located on insitu ground to the side of the embankment. Emergency spillways are usually side channel spillways; however, principal spillways may also be side channel spillways. Side channels may be constructed with energy dissipation structures, such as baffles or stilling basins, to reduce discharge velocity and energy.

Figure 6-3 Concrete-lined side channel spillway with stilling basin at outlet.

Conduit Spillway - A spillway consisting of a closed channel, or conduit, that conveys the reservoir discharge under or through the dam embankment. The closed channel may be a vertical, horizontal, or inclined shaft and may be used in conjunction with most forms of control sections, including overflow crests, drop inlet entrances, and side channel crests. Conduit spillways are sometimes used without another type of control structure.

Ogee Spillway - An overflow weir in which the cross section of the crest, downstream slope and bucket have an “S” (or ogee) form of curve. The shape is designed so that the underside of the nappe matches the upper extremities of the weir.

Spillways are critical to the safe operation of every dam and must be inspected very closely. Many problems that occur at spillways may not be visible until damage or failure occurs. This is particularly true with problems that develop along or under conduits in embankments, or under concrete linings. The riser on a shaft spillway is almost always submerged in the reservoir, making it difficult if not impossible to examine all parts of the spillway. Boat access may be required on some, while professional scuba divers may be required to inspect others. For this reason, inspectors must be alert for any signs of deterioration or damage that may be present, but may not be visible during a surface inspection.

Figure 6-4 illustrates an embankment dam configuration that is commonly used in Indiana. The principal spillway is a concrete shaft spillway with a rectangular riser and a circular, concrete conduit for discharging the riser flows. The emergency spillway is a side channel spillway constructed on insitu ground. Anti-seep collars have been used to control seepage along the conduit, however they are no longer recommended.

Seepage, or filter, diaphragms are newer technology and have replaced the anti-seep collars as the preferred method of seepage control. A diaphragm is an engineered filter placed near the downstream end of the conduit that prevents seepage water from removing the soil from around or under the conduit. Filter diaphragms are commonly connected to a horizontal granular layer or pipe drain to convey seepage from the diaphragm away from the embankment. Anti-seep collars may contribute to piping problems and the embankment should be closely inspected for problems if they are used.

The outlet is the structure through which water can be freely discharged from a reservoir. Outlets are used to drawdown the reservoir level in dams, or to maintain a desired flow downstream of the dam. An outlet may also be referred to as a reservoir drain.

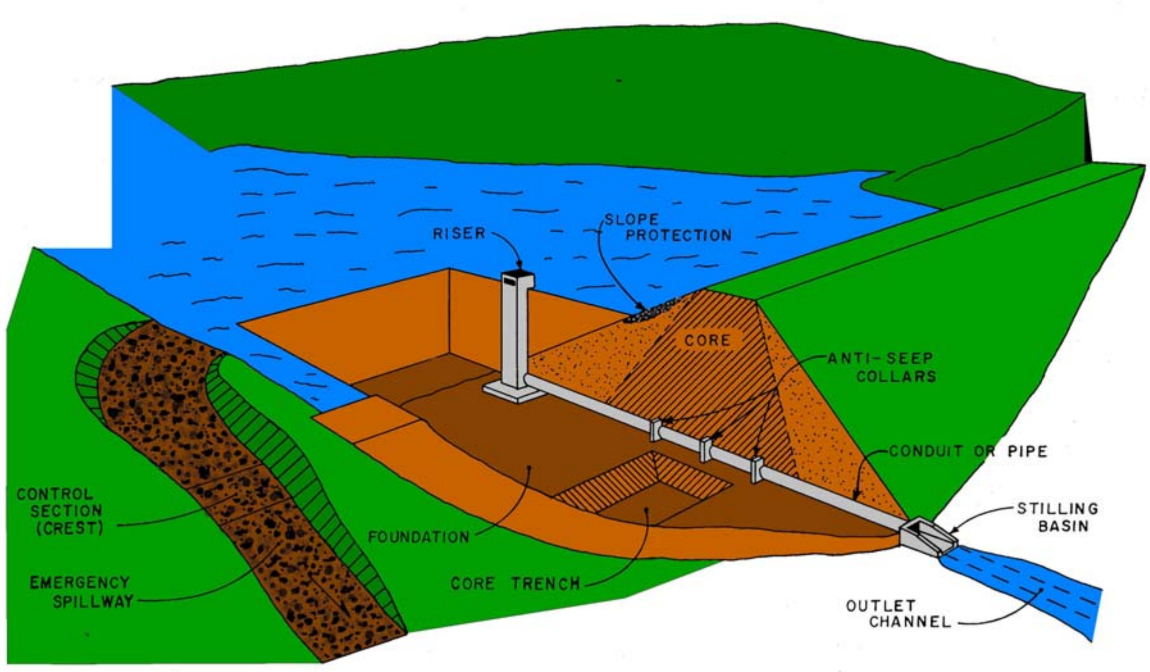


Figure 6-4 Section of a typical dam in Indiana, illustrating the principal and emergency spillways. Although anti-seep collars were commonly used in the past, they are no longer recommended for use.

The primary function of the outlet (also called outlet works, or outlet system) is to provide for the controlled release of water from the reservoir behind the dam. The outlet system is used to release water downstream for irrigation, dam repairs, emergencies, and other uses. The size of the outlet system is determined by the rate of demand downstream, or the desired rate of drawdown that may be needed for maintenance. Except in an emergency, the rate of drawdown of the reservoir should be slow; not exceeding one foot per 24-hour period is typical. In an emergency, drawdown should be accomplished as rapidly as possible without creating additional peril to the dam, its appurtenances, or the area downstream.

Outlet works components may include the following: entrance channel, intake structure, waterway or conduit, control section, terminal structure, access shafts, bridges, and tunnels, and operation/ maintenance stations.

The entrance channel (if present) conveys water to the intake structure of the outlet works. The intake structure establishes the ultimate drawdown level, guards against entry of trash, and may incorporate water control devices (valves) for flow regulation, or closure devices for dewatering the outlet works during visual inspection and maintenance. Intake structures may be vertical or inclined towers, drop inlets, or submerged, box-shaped structures. Intake elevations are determined by the head needed for discharge capacity, storage capacity for siltation, the required amount and rate of withdrawal, and the desired maximum drawdown level.

The waterway conveys the released water from the intake structure to the point of downstream release. Waterways may be steel-lined sluiceways or ports through concrete dams, lined or unlined tunnels in abutments, or from the reservoir basin elsewhere, open channels, or closed conduits beneath the dam. Closed waterways may be designed for pressure and non-pressure flow. Pressure pipelines and penstocks may be extended through non-pressure conduits and tunnels, affording access and pressure relief.

The control section regulates the flow of water through the outlet works and may be located at the upstream or downstream limits of the waterway, at intermediate positions, or at several positions. It houses and supports control devices that proportion or shut off outflow. Types of valves and gates used for control devices include slide gates; commercial gate valves; butterfly valves; ring follower, fixed-wheel, and roller train leaf gates; needle, tube, jetflow, hollow-jet, and Howell-Bunger valves; and bottom-seal and top-seal radial gates. For satisfactory performance, the type of valve or gate must be matched to service conditions such as maximum head, flow velocity, in line or free discharge, fully open, closed, or partially open, and unbalanced or balanced head operation.

The terminal structure delivers the flows to the point of downstream release. The need for and the type of terminal structure are determined by the purpose of the outlet works. The terminal structures can be separate structures similar in principle to those for spillways, or the outlet releases may be conveyed through the spillway discharge conduit and terminal structure.

The inspector should visually inspect the outlet and all of its components. Arrangements should be made with the dam owner to have someone operate the outlet; **the inspector should not operate the outlet** to avoid potential liability issues involving the release of water, or possible breakage or sticking (in open position) of control valves.

6.2 ITEMS OF CONCERN

There are four general types of problems that can prevent a spillway or outfall from functioning properly: (1) cracks and structural damage; (2) inadequate erosion protection; (3) deterioration or lack of maintenance; and (4) obstructions. As soon as

Table 6-1
Items of Concern

1. Cracks & Structural Damage
2. Inadequate Erosion Protection
3. Deterioration
4. Obstructions

Special Concerns:
- Conduits
- Outlets

any of these problems is identified, remedial steps should be taken to correct the defect. Each of these types of problems is described in detail in this chapter. Additionally, special concerns of conduits and outlets are discussed separately, including visual inspection guidelines and testing procedures.

The spillway is a very important part of a dam. If it has not been designed with adequate capacity, or is not constructed and maintained properly, overtopping of the embankment may occur during a large storm. This could cause failure of the dam or its components and serious damage to downstream properties, or even death of downstream residents. A spillway should always be kept free of obstructions, have the ability to resist erosion, and be protected from deterioration. A dam and reservoir represent not only a potential public hazard, but also a substantial investment. The dam's owner can identify any changes in previously noted conditions that indicate a safety problem. A conscientious annual maintenance program should address and control most of the conditions described in this chapter. Quick corrective reaction to conditions requiring attention will promote the safety and long life of the dam and possibly prevent costly future repairs. The inspector must visually examine spillways and outlets for potential deficiencies to ensure the continued safety of the dam.

Figure 6-5 This dam's open channel spillway used a concrete control section; note that it failed and was almost totally washed away.

In general, spillways are either open channels or conduits. Open channel spillways are easier to inspect because they are typically easier to access. Steep sidewalls or flowing water in open spillways may make visual inspection dangerous for the inspector. Many dams in Indiana use pipes (or conduits) that serve as principal spillways or outlet structures. Pipes placed through embankments may be difficult to construct properly, can be extremely dangerous to the embankment if problems develop after construction, and are usually difficult to inspect and repair because of their location. Maximum attention should be directed to visually inspecting and maintaining these structures.

Frequent visual inspection of the spillway and outlet conduits is necessary to ensure that they are functioning properly. All conduits should be inspected thoroughly once a year as part of the maintenance inspection program. Conduits which are 30 inches or more in diameter can be entered and visually inspected with proper precautions and equipment. The conduits should be inspected for improper alignment (sagging), elongation, separation, displacement at joints, deformation, undermining, cracks, leaks, surface wear, loss of protective coatings, corrosion, and blockage. Problems with conduits occur most often at joints, therefore special attention should be given to the joints during the visual inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint filler material. Open joints can permit erosion of embankment material or cause leakage of water into the embankment during pressure flow. The outlet should be checked for signs of water seeping along the exterior surface of the pipe. A depression in the soil surface over the pipe may be a sign that soil is being removed from around the pipe.

The inspector must be careful when entering conduits. These areas are potentially confined spaces and may contain noxious gases, or may lack sufficient oxygen. If in doubt, the inspector should use a portable gas meter to check the air in a conduit before entering. Conduits also present potential hazards to the inspector's physical safety.

The inspector should look carefully for signs of structural damage to spillways and outlets that could create a safety hazard. Structural damage usually results from foundation problems or settlement of fill material around or under the structure. Cracking and displacement of the structure are typical outward signs of structural damage.

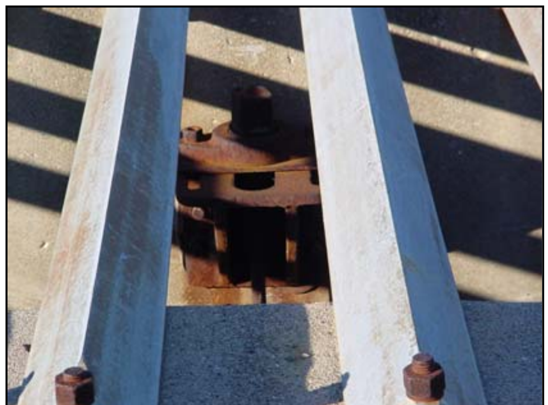


Figure 6-6 The valve stem for the outlet in this dam is conveniently located in the riser; notice the rust forming on the metal components.

Outlets (drains or drawdown structures) should be operated every time formal technical or maintenance inspections are performed. In addition, they should be operated at least twice annually and especially just before the annual flood season, typically March in Indiana. This will help keep the equipment in working order and verify its performance. Unused outfall valves and controls can become corroded or blocked with sediment, so routine testing can help maintain these devices. Precaution must be exercised to prevent downstream flooding by releasing too much water. The dam owner is responsible for operating the outlet structures; the inspector should not assume this responsibility.

A visual inspection of the outlet may require advance planning to allow outflows to be shut off and inundated areas to be pumped out. Inspection by the owner or his representative can usually determine if a problem exists with the outlet. In most cases a qualified dam safety professional will be required to recommend corrective action when problems are found.

The remainder of this chapter focuses on the visual inspection and identification of specific problems that may be found on spillways and outlets. The information is presented by the type of deterioration (i.e., cracks and structural damage, inadequate erosion protection, deterioration, and obstructions) for the various types of spillways and outlets that may be encountered.

6.3 CRACKS AND STRUCTURAL DAMAGE

Minor cracking is sometimes present on concrete-lined spillways, concrete pipes, and conduits. Significant cracking, however, often causes (or is the result of) vertical and/or horizontal displacement, and misalignment of the structure. Structural damage may affect any type of spillway or outlet structure, and is usually caused by foundation problems in the soil or rock below the structure in question. Cracks may also be considered as deterioration, but they are discussed separately because of their importance to structure stability. Concrete structures are often undermined by water seepage or piping, and eventually experience structural damage as the concrete settles into the underlying voids.

6.3.1 Concrete Spillways and Outlets

Cracks are commonly encountered defects for concrete spillways; cracks are less common in outlets, although they still occur. Cracks may be caused by foundation problems, water pressure, concrete expansion, freeze-thaw effects, poor concrete mix design, poor construction practices, and chemical reactions. The discussion of cracks in this section applies to both spillways and outlets. The open, concrete spillway in Figure 6-7 has extensive cracking and deterioration and should be repaired immediately.

Figure 6-7 Concrete spillway showing extensive cracking and general deterioration, most likely a result of freeze-thaw effects.

By definition, a crack is a separation of portions of a concrete structure into one or more major parts, and is usually the first sign of concrete distress. There are two general categories of cracking typically found on concrete structures: (1) **individual cracks**, and (2) **pervasive cracks**. A concrete structure may have one or a limited number of individual cracks that can be individually measured and documented during the visual inspection. Structural cracks are usually individual or a number of individual cracks. Often, numerous cracks may be visible within areas of a concrete surface, or the cracking may affect the entire surface. This condition is known as pervasive cracking. Pervasive cracking tends to have a number of typical appearances produced by specific causes. Pervasive cracking usually is a sign of some form of concrete deterioration.

When the concrete exhibits pervasive cracking and has extensively cracked surfaces, the primary focus of the visual inspection should be the location, nature, and extent of cracking rather than the dimensions of individual cracks. If individual cracking is observed, the location and dimensions should be recorded for each crack and whether or not they are structural or surface cracks.

Cracks in the concrete may be structural or surface cracks. Surface cracks are generally less than a tenth of an inch wide and deep. These are often called hairline cracks and may consist of single, thin cracks, or cracks in a craze/map-like pattern. A small number of surface or shrinkage cracks is common and does not usually cause any problems. Surface cracks are commonly caused by freezing and thawing, poor design or construction practices, and alkali-aggregate reactivity. Large cracks present the greatest potential for safety concerns and usually develop as a result of structural problems. Large cracks will usually result in rapid deterioration of the spillway. Misalignment and displacement of spillway walls and chute slabs are often associated with large cracks. These cracks may be caused by uneven foundation settlement, foundation erosion, slab displacement, or excessive earth or water pressure. Large cracks will allow water to wash out the materials below or behind the concrete slab, causing erosion and leading to more cracks. Extensive cracking can cause the concrete slab to be severely displaced, dislodged, or washed away by the flow. When large cracks are observed, the inspector should look for structure alignment and foundation problems.

Figure 6-8 Concrete spillway with structure damage.

Cracks provide openings in the concrete that permit further deterioration of the concrete. A concrete spillway may have to withstand considerable hydrostatic pressure from the reservoir and groundwater. Hydrostatic pressure acting along cracks through the concrete structure may exert dangerous uplift forces, possibly leading to lateral propagation of the cracks and uplifting, settlement, or sliding of a portion of the structure. A severely cracked concrete spillway should be examined by a qualified dam safety professional.

The inspector should determine if the cracking is an individual or limited number of individual cracks, or pervasive cracks. The American Concrete Institute (ACI) has developed standardized terms to describe the appearance of individual and pervasive cracks. After the inspector has classified the cracks as either individual or pervasive crack, he/she should then further describe the cracks using the ACI terminology.

6.3.1.1 Individual Cracks

Table 6-2
ACI Standardized Terminology for Individual Concrete Cracks

(1) Direction	**(2) Width**
Longitudinal	Fine: less than 0.5 mm
Transverse	Medium: between 0.5 and 2 mm
Vertical	Wide: over 2 mm
Diagonal	
Random	

(3) Depth (measure each crack)

Consistent with terminology used for cracking in embankment dams, some nomenclature for cracks in concrete dams differentiates cracks, on and parallel to the crest of a structure - termed longitudinal - from cracks on faces of the structure, which are designated as horizontal. ACI uses the term longitudinal to describe cracks in either location that are parallel to the crest. ACI 201.1, *Guide to Making a Condition Survey of Concrete in Service*, is a useful document that should be used if the inspector needs more information.

ACI standardized terms to describe the appearance of individual cracks includes direction, width, and depth. These terms are listed on Table 6-2; it is recommended that the inspector use this terminology to describe individual cracks in concrete structures. The same terminology applies to concrete dams. This terminology describes the crack based on its orientation, or direction, width, and depth, as summarized on the table.

A crack in a concrete conduit through an embankment dam could allow reservoir water under pressure to enter and erode the embankment along the conduit. Cracks that cause leakage into the embankment or into the pipe from the reservoir should be immediately repaired. These cracks are usually structural cracks in the conduit walls and floor, caused by uneven settlement or foundation erosion.

Large cracks may be an indication of structural problems and are potential safety concerns. The location, width, length, and orientation of the crack(s) should be recorded during the visual inspection. Large cracks are often the result of serious problems under the concrete. The inspector should also determine if concrete around the crack has deteriorated or whether reinforcing bars are exposed. Spillway retaining walls or chute slabs may be displaced from their original position as a result of foundation settlement, or earth or water pressure. The inspector can sight carefully at the upstream or downstream end of the spillway near the wall to determine if it has been tipped inward or outward. Relative displacement or offset between adjacent sections of concrete can be readily identified at the joint. The horizontal and vertical displacement should be measured and recorded. If a fence line was constructed on top of the retaining wall, it can be used to help determine if the wall is distorted. Fences are usually erected in a straight line at the time of construction, therefore a curve or distortion of the fence line may indicate that the wall has deformed. The entire spillway chute should form a smooth surface. Measurement of relative movement between neighboring chute slabs at the joint will give a good indication of the slab displacement. Large cracks and associated problems are usually easy to see during a visual inspection. A clear description of crack patterns should be recorded and photos taken to help in understanding the nature of the displacement.

A large crack is often a structural crack and may require immediate repair. A large crack in a concrete spillway or discharge channel also could allow erosion of underlying material, resulting in loss of support and failure of the spillway. A badly cracked channel wall might fall when subjected to pressure from a large discharge. The inspector should always closely evaluate large cracks and determine their potential impact to the safety of the dam.

6.3.1.2 Pervasive Cracks

ACI uses three general classifications to describe extensive, or pervasive cracking of concrete surfaces based on the shape of the cracks: (1) pattern cracking, (2) D-cracking, and (3) checking. Therefore, pervasive cracking should be further classified based on these shape descriptions. Figure 6-9 illustrates the different forms of pattern cracking that may be found on concrete structures.

<u>Pattern Cracking</u>

Pattern cracking is a form of pervasive cracking that consists of openings on a concrete surface in the form of a pattern, and is caused by either shrinkage of concrete near the surface or a volumetric increase in concrete below the surface layer. Thermal stress, alkali-aggregate reaction, and freeze-thaw actions cause changes in the volume of concrete.

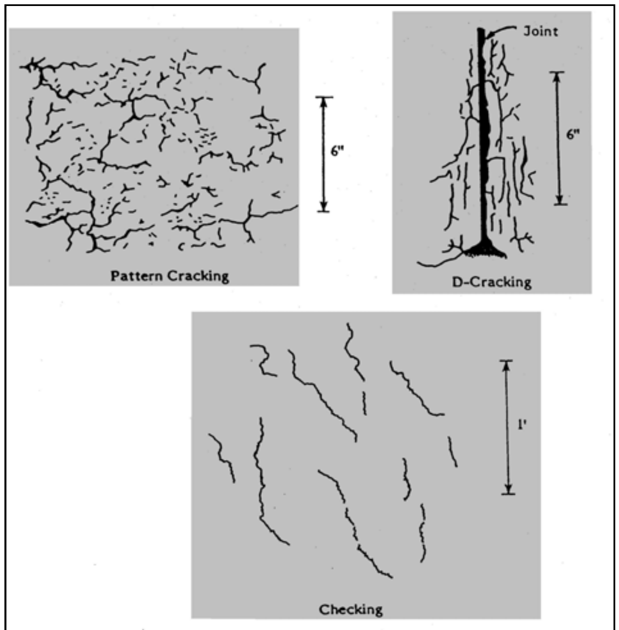


Figure 6-9 Different forms of pervasive cracking.

Cement hydration in mass concrete causes heat resulting in expansion. This, followed by differential cooling and shrinkage of the outer surface, is a major cause of thermal cracking. Reactions within massive concrete sections may continue to generate hydration heat for decades. Restraint by rigid foundations or old lifts of concrete is also a factor. Thermal cracks are deep, often extending through thin sections.

The inspector should be especially alert for thermal cracking in the massive concrete monoliths of concrete structures or dams. A pattern of hairline cracks in an orthogonal, blocky "dried mud puddle" configuration inside of galleries, usually accompanied by considerable leakage, is a sign of thermal cracking. Another sign of thermal cracking is the presence of vertical cracks continuous through walls, ceilings, and floors of transverse galleries resulting from cooling of concrete and restraint near the foundation. If thermal cracking is suspected, installing temperature gages for temperature studies provides a means to collect relevant data.

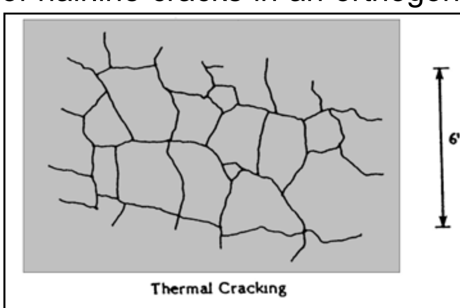


Figure 6-10 Illustration of thermal cracking.

If available, the mix designs for the dam structure should be reviewed. Failure to use low-strength concrete for the interior and high-strength concrete on the exterior of the structure may have promoted thermal cracking.

Construction records should be checked for a lack of such measures as use of thinner lifts, controlling concrete placement temperature, replacement of cement with pozzolan, and a reduced construction rate to deal with hydration heat.

Alkali-aggregate reaction can also cause pattern cracking. This condition is a reaction between soluble alkalis in the cement and silica in the aggregate and can cause abnormal expansion and cracking that may continue for many years. If the inspector observes pattern cracking in areas exposed to wet-dry cycles, the cause may be alkali-aggregate reaction. Alkali-aggregate reaction is described more fully in the following subchapter on deterioration.

Freeze-thaw action is another common cause of pattern cracking and D-cracking; cracking increases geometrically with each freeze-thaw cycle. The freeze-thaw cycle starts when water enters pores, cracks, and joints in the concrete. When temperatures drop, water in the concrete freezes and expands, causing the concrete to crack. Water then enters the new cracks, and when temperatures drop again, the water freezes and expands, forcing the cracks to open wider. The pores and spaces in concrete must be nearly saturated for freeze-thaw action.

The inspector should examine areas of concrete exposed to moisture for damage from freeze-thaw action. Exposed horizontal surfaces such as slabs, and vertical walls near the water line are especially subject to freeze-thaw damage. Surfaces with a southern exposure can have accelerated damage due to daily freeze-thaw cycles. Use of entrained air helps protect concrete from freeze-thaw damage. Lack of entrained air in pre-1940 concrete elements, or an improper percent of entrained air, may have resulted in concrete that is vulnerable to damage.

D-Cracking

D-cracking is another form of pervasive cracking that consists of fine parallel cracks at close intervals, usually along joints or edges. This pattern of cracking is an early sign of damage from freeze-thaw action. Low-quality limestone aggregates are commonly the cause of D-cracking. D-cracking is commonly seen at the exposed corners of slabs and walls formed by joints.

Checking

Checking consists of the development of fine, pervasive cracks on the surface of concrete; the cracks generally show no evidence of movement, are shallow, and are closely spaced at irregular intervals. Cracks that display checking may be several feet long.

Checking is usually caused by expansion and contraction or shrinkage of the concrete surface with alternating wet-dry periods. Rapid drying of newly placed concrete may also result in checking of the concrete surface.

6.3.1.3 Hairline Cracks

Hairline cracks are surface cracks and are generally less than a tenth of an inch wide and deep. They may consist of single, thin cracks, or pervasive cracks in a craze/map-like pattern, as described above. A small number of surface or shrinkage cracks is common and does not usually cause any problems. Minor or hairline surface cracking can be caused by weathering, the quality of the concrete that was applied, freezing and thawing, poor construction practices, chemical reactivity, and other factors as described above under pervasive cracks.

Hairline cracks are usually harmless and pose no immediate threat to the stability of the spillway structure. This type of cracking should be noted and monitored on a routine basis for signs of additional deterioration. The location, orientation, length and width of the hairline cracks should be reported by the inspector.

The results of this minor cracking can be the eventual loss of concrete, which exposes reinforcing steel and accelerates deterioration. Generally, minor surface cracking does not affect the structural integrity and performance of the concrete structure.

Even if a crack itself does not present a serious threat, the mechanism causing the crack may threaten the structure. Cracking in concrete may be a visible indication of stress or movement which the concrete cannot accommodate. The underlying cause of cracking may pose an immediate threat to the dam and should be determined. Therefore, the inspector should try to determine the cause of any cracking that is present.

6.3.1.4 Structural Cracks

The inspector should be able to recognize cracks that may affect the safety of the dam; these cracks are commonly called **structural cracks**. A structural crack compromises the integrity of a concrete structure and therefore may pose a safety problem. In appearance, a structural crack may be:

Figure 6-11 Large structural cracks with vertical displacement.

- Diagonal or random with abrupt changes in direction
- Wide (greater than 0.25 in.), with a tendency to increase in width

- Adjacent to concrete that is noticeably displaced
- Occasionally narrow and diagonal, indicating inadequate design for shear stresses
- Long, single or multiple diagonal cracks with displacement and misalignment

Structural cracks usually result from movement of portions of a structure or overstressing. External stresses may be caused by extreme or differential loading conditions, foundation settlement, voids under or along the structure, seismic activity, design or construction errors, or deficiencies in the concrete materials. Flaws in structure design may result in stresses too great for the concrete to withstand. Concrete mixtures with deficient strength or elastic properties may crack under design stresses. Poor construction techniques may also be responsible for deficiencies that promote cracking. Deep, wide cracking is usually due to stresses which are primarily caused by shrinkage, structural loads, or loss of foundation material.

Figure 6-12 Serious structural damage requires replacement of spillway.

Structural problems are indicated by cracking, exposure of reinforcing bars, large areas of broken-out concrete, misalignment at joints, undermining, and settlement in the structure. Rust stains that are noted on the concrete may indicate that internal corrosion and deterioration of reinforcement steel is occurring. Spillway floor slabs and upstream slope protection slabs should be checked for erosion of underlying base material otherwise known as undermining. Concrete walls and tower structures should be examined to determine if settlement and misalignment of construction joints has occurred. Cracks extending across concrete slabs which line open channel spillways or provide upstream slope wave protection can indicate a loss of foundation support resulting from settlement, piping, undermining, or erosion of foundation soils. Piping and erosion of foundation soils may be the result of inadequate under-drainage and/or cutoff walls.


Figure 6-13 This concrete spillway was completely destroyed as a result of foundation erosion.

Items to consider when evaluating a suspected structural crack are the concrete thickness, the size and location of the reinforcing steel, the type of foundation, and the drainage provision for the structure. Floor or wall movement, extensive cracking, improper alignments, settlement, joint displacement, and extensive undermining are signs of major structural problems. Drainage systems may be needed to relieve excessive water pressures under floors and behind walls. Because of their complex nature, major structural repairs require professional advice and design. Part 2 of the Indiana Dam Safety Inspection Manual describes repair operations in more detail. The particular method of repair will depend on the size of the job and the type of repair required.

Cracks through concrete surfaces exposed to flowing water may lead to the erosion or piping of embankment or foundation soils from around and/or under the concrete structure. In this case, the cracks are not the result of a problem but are the detrimental condition which leads to piping and erosion. Seepage at the discharge end of a spillway or outlet structure may indicate leakage of water through a crack. Proper under-drainage for open channel spillways with structural concrete floors is necessary to control this leakage. Flows from under-drain outlets and pressure relief holes should also be observed and measured. Cloudy flows may indicate that piping is occurring beneath or adjacent to the concrete structure. This could be detrimental to the foundation support.

The inspector should look for structural cracks at areas of stress concentrations, such as: corners of openings; contraction joints; areas of large temperature gradients, foundation and abutment material changes, slope changes, or direction changes relative to the section of the structure. Temperature variations between the air and reservoir water in cold weather can cause cracks extending from the structure crest down each face. Structural cracks often are wide, change widths with load changes or temperature cycles, or include significant leakage. The inspector should compare his/her observations with the drawings, photos, or sketches from past inspections, and be alert for new cracks and for changes that depart from past trends.

Concrete surfaces adjacent to contraction joints and subject to flowing water are of special concern, especially in chute slabs. The adjacent slabs must be flush, or the downstream slab should be slightly lower to prevent erosion or cavitation damage of the concrete and to prevent water from being directed into the joint during high velocity flow.

All weep holes should be checked for the accumulation of silt and granular deposits at their outlets. These deposits may obstruct flow or indicate loss of support material behind the concrete surfaces. Weep holes in the concrete are used to allow free drainage and relieve excessive hydrostatic pressures from building up underneath the structure. Excessive hydrostatic pressures underneath the concrete could cause it to heave or crack which increases the potential for accelerated deterioration and undermining. Periodic monitoring of the weep hole drains should be performed and documented on a regular and routine basis to ensure that they are functioning as designed.

Tapping concrete surfaces with a hammer or some other device will help locate voids if they are present as well as give an indication of the condition and soundness of the concrete. Voids will produce a "hollow" sound when the concrete is tapped with a hammer or other object.

Visual inspection of intake structures, trash racks, upstream conduits, and stilling basin concrete surfaces that are below the water surface is not readily feasible during a regularly scheduled inspection. Typically, stilling basins require the most regular monitoring and maintenance because they are holding ponds for rock and debris, which can cause extensive damage to the concrete surfaces during the dissipation of flowing water. Therefore, special inspections of these features should be performed at least once every five years by either dewatering the structure or when operating conditions permit. Investigation of these features using experienced divers is also an alternative.

6.3.1.5 Reporting Cracks

The inspector should examine and report all types of cracks, using the ACI terminology described earlier. Therefore, the inspector will have to be able to identify and describe cracks to be able to effectively inspect concrete structures. Structural cracks are serious and should be carefully evaluated and documented.

Table 6-3
Description of Cracks

Individual Cracks	**Pervasive Cracks**
- Direction - Width - Depth	- Pattern Cracks - D-Cracks - Checking
Hairline Cracks	**Structural Cracks**
- Individual Cracks - Pervasive Cracks	- Individual Cracks are typical

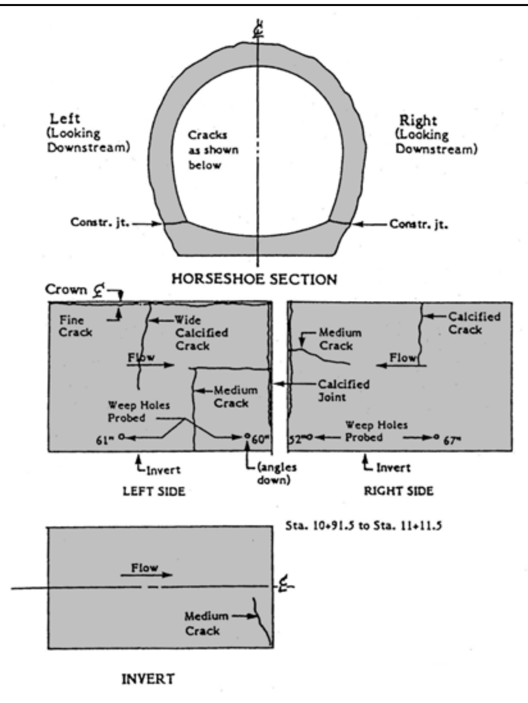


Figure 6-14 Sketch of cracking observed during an inspection.

If the problem associated with the cracks is serious and potentially affects the integrity of the dam or its appurtenant works, a crack survey may be warranted. A crack survey is an examination of a concrete structure for the purpose of locating, recording, and identifying cracks and of noting the relationship of the cracks with other signs of distress. A design drawing or inspection drawing is often used to record the location and extent of cracks in this type of survey. A grid system established with paint or chalk on a structure's surface can be used as an aid to determine crack locations.

A crack survey should identify characteristics of the cracks such as, length, width, direction, trend, depth, offset, and location. It should also describe the cracks based on the definitions presented above.

For monitoring purposes, measurement points should be marked, and the sharp edges of cracks should be protected with a thin coat of clear epoxy. This will prevent spalling or degrading of the edges which would give falsely high width measurements. The inspector should use a comparator, feeler gage, or a handheld illuminated microscope to measure the width. (A comparator is printed or inscribed with lines of various widths on a transparent background. The inspector places the comparator over a crack and matches crack width to a line. Two versions of comparators exist. One is a lighted magnifying glass with an eyepiece scribed with lines. The other is a clear plastic card printed with lines.)
Whenever feasible, external cracks should be correlated with internal cracks. Where repairs have been made to the concrete, crack surveys are difficult to perform and may be unreliable because cracks beneath the repairs may indicate deficiencies at greater depths. It is significant, however, to note whether new cracks have developed in the repaired concrete. Such cracks may indicate continuing structural problems.

Other conditions or deficiencies are often associated with cracking, such as leakage, deposits from leaching or other sources, and spalling of crack edges. These conditions should also be reported by the inspector.

The inspector should always look for seepage in or out of cracks. Water from seepage or leakage may compound the problem, leading to further degradation, including:

- The development of excessive hydrostatic pressures on some portions of the structure
- Attacking the concrete chemically
- Freeze-thaw damage to concrete
- Erosion or solution of the foundation material
- Leaching of the concrete

Chemical analysis of leakage water and deposits may be advisable if other problems begin to develop.

Sometimes the leakage source can be determined by simple measurements comparing leakage water temperature with ground water and reservoir temperatures. Dye tests are another means of identifying leakage sources. Approved dyes can be placed in the water upstream of the structure, in drill holes, or in other accessible locations. The location and time the dyes appear downstream can locate the sources and velocity of leakage.

The most common leakage measuring devices include a container and stopwatch, weir, flume, and flow meter. A container and a stopwatch may be used to measure the leakage from a crack if the water can be conveniently contained. It may be necessary to use a plate or other device to get the leakage to spring free from the concrete surface and into the container. Sometimes the seepage water may have to be collected or measured at a point downstream of the source to make it convenient to do so. It is not always easy to collect and measure water flow rate from seeps; the inspector may have to be creative to implement a collection and measurement procedure.

Movement between adjacent concrete surfaces or between concrete surfaces and the foundation can be measured with survey instruments, foundation baseplates, settlement sensors, inclinometers, extensometers, tiltmeters, plumblines, measurement points, calibrated crack monitors, joint meters, embedded strain meters, stress meters, and temperature gages. The inspector should note all instances when monitoring equipment reveals enlargement or other changes in a crack. Also, he/she should examine other instrumentation measurements for evidence of conditions that may have caused changes in the crack.

If cracking is observed during a visual inspection of a concrete spillway or outlet, the following actions should be taken:

- Photograph and record location, depth, length, width, and offset of the cracks.
- Note prominent cracks, cracking over large areas, and the trends for particular cracks.
- Look for structural damage, including misalignment, settlement, vertical and horizontal displacement.
- Look for any surrounding cracks.
- Classify and describe the cracks using the terminology defined above.
- If extensive new cracking is observed, consider initiating a crack survey to thoroughly document all cracks in the structure and their characteristics. Contact a qualified dam safety professional if there is uncertainty about the severity of cracking or if the following conditions are observed:
  - A major new crack
  - A crack(s) that has changed significantly since the last inspection
  - Cracks indicating movement that might be detrimental to the structure or to equipment operation
  - Significant leakage
- Look for evidence of seepage or saturated soils in or below the cracks. Also look for signs of foundation soil erosion. If there is an excessive amount of water, or water which cannot be handled by the drainage system is flowing through a crack, recommend repairs. Check with a concrete specialist to identify appropriate repair procedures.
- Determine if other dam structures, such as the embankment, could be affected by the cracking in the spillway.
- Closely monitor the cracks for changes.
- Try to determine the cause of the cracking; this can help identify effective corrective actions.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe or gets progressively worse. Serious cracking or repair operations may require lowering the reservoir level.
- Recommend appropriate corrective action be taken to repair or to replace the

damaged spillway areas. The recommended corrective actions should be consistent with the inspector's training and experience.

If instrumentation has been installed to monitor serious cracks, the data may supply reasons for the cracking. Measurements of leakage and movement are particularly important for evaluating cracks, as well as for evaluating joints, which also are subject to leakage and movement.

Any recommendations the inspector may make for simple corrective actions should be reviewed by qualified dam safety professionals. Extensive corrective actions that may be taken in response to inspection findings include:

- For cracks that may be leaking but there is not a high hydrostatic head, treatment may consist of grouting the crack by injecting either an elastomeric filler (if crack movement is anticipated) or a rigid epoxy mortar.
- For cracks where leakage is accompanied by high hydrostatic pressure, installation of a drainage system may be necessary.
- If structural analysis shows a crack has affected the structure's stability, post-tensioning between components of the structure or between the structure and foundation rock or anchors may be required.
- Collapsed slabs and wall may need complete replacement and foundation repair.
- Concrete conduits may need to be replaced if the damage is severe. Conduit linings may also be applicable.

Repair materials that may be used include epoxy grout, methacrylates, polymerized concrete or mortar, fiber-reinforced concrete, and very low water-cement ratio concrete. Part 2 of the Indiana Dam Safety Inspection Manual provides additional details for the maintenance and repair of concrete structures.

6.3.2 Earthen Spillways

Figure 6-15 Earthen spillways located on fill are not recommended and should be closely monitored.

Earthen spillways may be affected by the same type of cracking problems encountered on embankments (Part 3, Chapter 5). However, cracks observed in earthen spillways are usually not as critical as those on embankments since the spillways are typically on insitu ground. Desiccation cracks in an earthen spillway or channel are usually not regarded as a functional problem, but should be noted on the inspection report nonetheless. Deep cracks that are wider than ½ inch may be signs of slope stability issues, including sloughing or sliding. The side walls of earthen spillways are usually more vulnerable to stability problems than the floor since they are usually steeper and may contain groundwater seeps. Seepage from the reservoir or insitu ground may saturate spillway soils, making conditions for a slide favorable. Cracks that are deep and relatively wide (greater than ½ inch) may be an indication that a slide is developing in the soil. Cracking should be considered as a serious problem if it is the beginning of a slide. Slides are structural problems that can reduce the spillway capacity by obstructing the flow path, or can lower the elevation of the spillway control section, depending on the location of the slide. The inspector should monitor the condition frequently for sloughing, bulging, or the formation of scarps.

If cracking or slides are observed during a visual inspection of an earthen spillway, the following actions should be taken:

- Photograph and record location, depth, length, width, and offset of the cracks or scarps, if present.
- Make sure that the spillway control section and discharge channel are on insitu ground. If not, note this as a serious concern.
- Look for any surrounding cracks.
- If a bulge is present, closely inspect the area above the bulge for cracking or scarps which indicate that a slide is the cause. Probe the bulge to determine if material is excessively moist or soft. Excessive moisture or softness usually indicates that a slide is the cause.
- Look for evidence of seepage or saturated soils in or below the cracks or slide. Probe the entire area to determine the condition of the surface material.
- Determine if other dam structures, such as the embankment, could be affected by the cracking or slide in the spillway.
- Closely monitor the cracks or slide for changes.
- Consult a qualified dam safety professional to determine the cause of the cracking or slide if it is severe or gets progressively worse. Serious cracking, slides or repair operations may require lowering the reservoir level. In most instances, deep-seated slides near or at the control section will require the lowering or draining of the reservoir to prevent the possible breaching of the dam.
- Recommend appropriate corrective action be taken to repair or to replace the damaged spillway areas.

The inspector should consider the worst case scenarios when evaluating earthen spillways. This typically means a condition in which the spillway is flowing at maximum design levels. The inspector should consider the frequency, duration, depth, and velocities of potential spillway flows.

6.4 INADEQUATE EROSION PROTECTION

When a large storm occurs, the spillway system is expected to carry a large amount of water for many hours. Severe erosion damage or complete wash-out could result if the spillway lacks the ability to resist erosion. If the spillway is excavated in a hard rock formation or lined with concrete, erosion is usually not a problem. But, if the spillway is excavated in sandy soil, deteriorated rock, clay, or silt deposits, erosion protection is very important. Generally, resistance to erosion can be increased if the spillway channel has a mild slope, or if it is covered with a layer of grass or riprap with bedding material.


Figure 6-16 Poor spillway lining.

Erosion at a spillway outlet, whether it be a pipe or overflow spillway, is one of the most common erosion problems encountered. Severe erosion or undermining of the outlet can displace sections of pipe, cause slides in the downstream slope of the dam as erosion continues, and eventually lead to complete failure of the spillway or dam. Water must be conveyed safely from the reservoir to a point downstream of the dam without endangering the spillway or embankment. Often the spillway outlet is adequately protected for normal flow conditions, but not for extreme flows. It is easy to underestimate the energy and force of flowing water and/or overestimate the resistance of the outlet material (earth, rock, concrete, etc). The required level of protection is hard to establish by visual inspection, but can usually be determined by hydraulic calculations performed by a professional engineer. Missing rocks in a riprap lining can be considered as a breach in the protective cover, and this should be repaired as soon as possible. The inspector should look for signs of erosion and inadequate erosion protection at the outlet of all spillways and outlets.


Figure 6-17 Riprap lining was completely washed away during a significant storm event, exposing the geotextile filter.

Stilling basins are often used at outlets to absorb the discharge energy. Stilling basins consist of a lined depression at the outlet of the spillway or outlet conduit. Stilling basins are commonly lined with riprap and a suitable bedding/filter material. Displaced riprap in stilling basins can result in

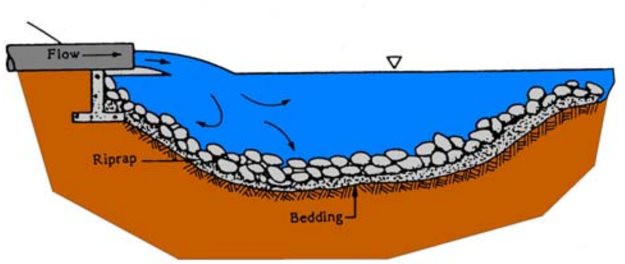


Figure 6-18 Typical rock-lined stilling basin at spillway outlet.

additional scouring in the basin which creates a deeper or larger depression and sedimentation downstream. If the scouring is serious, it can erode the toe of embankment dams, or undermine the outlet of spillways and outlets. The inspector should look for signs of rock displacement and scouring, particularly at the downstream end of the basin, and sedimentation in the receiving channel.


Figure 6-19 Grass lined outlet channel that was not designed for the flows it experienced, resulting in severe erosion.

Vegetative lining (grass) is often used in emergency spillway discharge channels. Grass linings can protect soil on relatively flat slopes and low discharge velocities. Typically, grass linings are adequate for water velocities of 5 ft/s or less. Bare spots, or areas where the grass is sparse, are susceptible to erosion problems and should be carefully inspected for erosion rills and gullies. Wide grass-lined spillways should be examined for erosion gullies and rills from stormwater runoff within the spillway.


Figure 6-20 Severe gully erosion.

Runoff will often concentrate in specific areas in the spillway and erode the surface soils. Although this is usually not a problem, it should be corrected before the erosion gullies get too deep. Shallow erosion rills should be monitored for additional damage from rainfall. Erosion rills and gullies generally will get worse with time. The inspector should determine the cause for the formation of the erosion features and recommend repairs that correct this problem. Often it is the result of uneven grading practices that tend to make the runoff flow to one spot or route in the spillway.

Many new synthetic lining materials are also available that will protect soil spillways from erosion at much higher velocities than grass. The degree of protection of these materials varies with the manufacturer and type of material. These materials are generally installed as blankets. These materials should be inspected for undermining, tearing, displacement, and exposure to the sun (will deteriorate).

Reservoir outlet works usually discharge into the spillway terminal structures, and the discharge from these structures may be intermittent. When the outlets have a separate outfall point and terminal structure, they should also be examined in the same manner as the spillway structures.

During the visual inspection, the inspector should look for inadequate erosion protection:

- Make sure that the grass, riprap, or other erosion protection is adequate to prevent erosion. Bald areas or areas where the surface protection is sparse are more susceptible to surface runoff and flowing water problems.
- Look for gullies, ruts, or other signs of surface runoff erosion. Be sure to check the low points at the spillway outfall, and areas where stormwater runoff can concentrate.
- Check for any unique problems, such as livestock or recreational vehicles that may be contributing to erosion.

If inadequate spillway protection is observed, the inspector should:

- Record the findings and photograph the area.
- Determine the cause and extent to which the spillway has been damaged (i.e., spillway foundation or soil material has been removed).
- Recommend that corrective action be taken to repair or to replace the inadequate spillway protection.
- Consult a qualified dam safety professional if necessary.

If erosion is observed, the inspector should:

- Record his/her findings and photograph the area.
- Determine the extent, severity, and cause of the damage.
- Recommend that corrective action is taken to repair the areas damaged by surface runoff and that measures are taken to prevent more serious problems.
- If spillway control sections need repaired, or extensive embankment excavation is required, the reservoir level may need to be lowered.

6.5 DETERIORATION

6.5.1 Overview

Deterioration is any adverse change on the surface or in the body of spillways and outlets that causes the structure to separate, break apart, or lose strength. A spillway cannot be expected to perform properly if it is deteriorated. The term, deterioration, is most commonly used in reference to the general condition of a construction material such as concrete, rock, metal, plastic, or wood and can result in the complete destruction of a material. The amount of deterioration which has occurred in a material is gaged with respect to its original condition. Deterioration of a material is normally due to the forces of nature such as wetting and drying, freezing and thawing, oxidation, decay, ultraviolet light, and erosive forces of wind and water. Activities of humans can also contribute to deterioration by altering the chemical composition of water through application of chemicals on or near a dam, and by virtue of the use of the dam (mine tailings, waste storage or retention, and product storage). A subjective evaluation of the extent and possible effects of deterioration should be made. Sometimes deterioration will be complete enough to result in other detrimental conditions. These include riprap deterioration because of bedding erosion, structural failures of concrete because of reinforcing corrosion, erosion and piping due to metal pipe corrosion, and plastic pipe cracking because of ultraviolet light deterioration.

Figure 6-21 General deterioration of a concrete spillway as a result of multiple causes.

Outward signs of deterioration include conditions such as collapse of side slopes, weathering of material, disintegration of riprap, breakdown of concrete lining, erosion of the concrete spillways, sloughing of discharge channels, excessive siltation of a stilling basin or discharge channel, and loss of protective grass cover, etc. These conditions can lead to flows under and around the protective material which can cause severe erosion. Remedial actions should be taken as soon as any sign of deterioration has been detected, even during storm flows. Cracks are a form of deterioration; cracking was discussed in detail earlier.

The inspector should attempt to understand as fully as possible why deterioration has occurred. Understanding the cause may reveal a solution, or measures that would prevent further damage. A large concrete spall adjacent to a joint, especially on a spillway slab, will require careful examination of the joint. As an example, loss of joint filler and replacement with sand or sediment can make joints too rigid to expand, causing spalling. Cleaning debris from joints and application of new joint filler might prevent further spalling.

6.5.2 Concrete Structures

6.5.2.1 Overview

Most concrete structures in Indiana experience some form of deterioration due to the severe nature of the climate and the dam environment. Typical types of concrete deterioration are summarized on Table 6-4. Most forms of concrete deterioration develop over a relatively long period of time with visual warning signs. So there is usually sufficient time to repair the structure before total failure occurs.

Table 6-4
Common Types of Concrete Deterioration

- Disintegration
- Scaling
- Spalling
- Popouts
- Pitting
- Efflorescence
- Drummy concrete
- Faulty concrete mixes
- Chemical attack
  - Sulfate attack
  - Acid attack
  - Alkali-aggregate reaction
- Metal corrosion
- Erosion
- Joint deterioration
- Cavitation
- Surface defects

Deterioration of concrete may be caused by many factors, including weathering, mechanical impacts, internal pressure, drying shrinkage, thermal stress, chemical action, leaching by water seepage, poor concrete mixes, poor concrete design, and freeze-thaw action. The use of excessive mix water is the single most common cause of damage to concrete. It may be difficult to isolate the specific cause for concrete deterioration. If the inspector is not sure, he/she should obtain professional help, or define the potential cause within a range of two or three possible causes. Sometimes, more than one mechanism may be involved. For example, cracking from thermal stress or drying shrinkage may lead to freeze-thaw action or leaching by water seepage.

Figure 6-22 Deterioration (cracking and spalling) of a concrete spillway from weathering and freeze-thaw effects.

Deterioration can weaken the design strength of a concrete structure and cause it to fail. Concrete deterioration may cause leakage and associated water pressures to increase. Deterioration may also result in distortion of a structure, causing binding of mechanical features such as gates which must operate to ensure the safety of a dam. The inspector should look for damage to other equipment and structures as a result of the concrete deterioration.

Deterioration may be isolated to some concrete elements, or may be due to a serious flaw in all of the concrete used in a structure. When stresses such as hydrostatic pressure or earth loads exceed the strength of a weakened element or structure, the dam or appurtenances may fail catastrophically. Some forms of deterioration may affect the safety of the structure immediately or in the near future. Seepage through a weakened concrete structure is a serious problem and needs immediate attention. The inspector should examine all concrete surfaces for seepage, and record any findings.

If a poor concrete mix is a possible cause for deterioration, the inspector should examine construction records for information about the concrete. Poor concrete mix design generally involves larger areas of the structure.

Figure 6-23 Concrete is deteriorating where these metal pipes enter a spillway riser as a result of differential expansion rates.

Many times concrete that is cast around corrugated spillway conduits creates problems due to differential expansion and contraction. The two different materials expand and contract at different rates which may result in cracks in the concrete. Another problem created by casting concrete around corrugated pipes is the potential lack of adhesion between the concrete and pipe surfaces, resulting in seepage along the pipe. The inspector should carefully examine areas where pipes and conduits are connected to other structures for signs of deterioration and seepage.

The inspector also should look for failure of repairs. Corrective action for concrete deterioration often includes removal of the deteriorated concrete and replacement with superior concrete or another repair material. Shallow repairs with epoxy materials may fail with large drops in air temperatures. Patched areas tend to shrink and crumble, and often the patch material does not bond well to the original surface.

6.5.2.2 Types of Deterioration

The inspector can use the following terms to describe concrete deterioration. Many of the terms are interrelated, with one type of deterioration producing one or more other types. The use of common terminology will help reviewers to better understand the defects and problems. ACI 116, Cement and Concrete Terminology, is a good source of information to use to describe concrete deterioration.

Disintegration is the crumbling or deterioration of concrete into small particles. Disintegration may result in possible failure of a concrete element or structure. Disintegration is one of the most serious forms of concrete deterioration. Disintegration can be a result of many causes such as freezing and thawing, chemical attack, and poor construction practices. All exposed concrete is subject to freeze-thaw, but the concrete's resistance to weathering is determined by the concrete mix and the age of the concrete. Concrete with the proper amounts of air, water, and cement, and a properly sized aggregate, will be much more durable. In addition, proper drainage is essential in preventing freeze-thaw damage. When critically saturated concrete (when 90% of the pore space in the concrete is filled with water) is exposed to freezing temperatures, the water in the pore spaces within the concrete freezes and expands, damaging the concrete. Repeated cycles of freezing and thawing will result in surface scaling and can lead to disintegration of the concrete. Hydraulic structures are especially susceptible to freeze-thaw damage since they are more likely to be critically saturated. Older structures (pre-1940) are also more susceptible to freeze-thaw damage since the concrete probably was not air entrained. In addition, acidic substances in the surrounding soil and water can cause disintegration of the concrete surface due to a reaction between the acid and the hydrated cement. The inspector should record visible signs of deterioration and try to determine the cause while at the site.

Figure 6-24 Severe disintegration of a concrete structure caused by poor concrete mix and weathering.

Large areas of crumbling (rotten) concrete, areas of deterioration which are more than about 3 to 4 inches deep (depending on the wall/slab thickness), and exposed rebar indicate serious concrete deterioration. If not repaired, this type of concrete deterioration may lead to structural instability of the concrete structure. A registered professional engineer should prepare plans and specifications for repair of serious concrete deterioration.

Scaling is the flaking or peeling away of the concrete or mortar surface. Scaling also results in susceptibility to further deterioration of the structure. Scaling is a milder form of disintegration.

Spalling is the loss of larger pieces of concrete (usually flakes or wedge-shaped pieces) from a surface, often at edges, caused by a sudden impact, external pressure, weathering, internal pressure (e.g., corroded rebar near the surface), expansion within the concrete mass, or fires built on or against structures. It often occurs in concrete on exposed surfaces at corners or at joints. Concrete spalling could be the result freeze-thaw action, a repair which has deteriorated, or stresses on a concrete structure which exceed the design. In spillways or outlets, it may be due to the impact of rocks or other debris against the flow surface. Joint spalling is usually due to erosion, weathering and ice damage but can also be due to structure movement. Other causes include reinforcing deterioration, chemical reactivity of aggregates, and vandalism. When observed, the particular structure should be checked for additional deterioration, displacements, and structural damage.

Figure 6-25 Concrete riser is spalling, exposing rebar and experiencing loss of concrete.

Figure 6-26 Side wall of spillway is spalling.

Spalling usually affects only the surface of the structure, so it is not ordinarily considered dangerous. However, if allowed to continue, spalling will cause structural damage, particularly if the structure is of thin cross section. Spalling often results in exposed reinforcing, leakage paths opened around embedded waterstops at joints, offsets on flow surfaces, and development of points of structural weakness. Repair is necessary when reinforcing becomes exposed to the elements. The method of repair of spalled areas depends upon the depth of the deterioration. Repair should be considered temporary unless seepage through the structure can be halted. However, if a spall is large and causes structural damage, a registered professional engineer should prepare plans and specifications to repair the spalling.

Popouts are a form of small scale spalling, and occur when a small portion of the concrete surface breaks away due to internal pressure. Popouts are usually formed as the water in saturated coarse aggregate particles near the surface freezes, expands, and pushes off the top of the aggregate and surrounding mortar to create a shallow conical depression. Popouts are typically not a structural problem, but they do make the structure susceptible to further deterioration.

Pitting is the development of relatively small cavities in the concrete surface caused by localized disintegration. Pitting usually results in susceptibility to further deterioration of the structure. It may be caused by a number of reasons, including weathering, mechanical damage, localized chemical attack, etc.

Efflorescence is the leaching of calcium compounds from within the concrete and deposition on the surface due to water leaking through joints, cracks, or the concrete itself. It appears as a white, crystallized substance on the concrete surface. The seepage water dissolves soluble calcium hydroxide from cement within the concrete and carries it to the exposed face of the concrete. As water evaporates from the concrete surface, calcium hydroxide is deposited. These deposits react with carbon dioxide in the air to form calcium carbonate or the hard white deposits normally observed. The problem with water seepage is that as calcium hydroxide is leached from the concrete around the joint or crack, the opening widens permitting increased seepage. Widening of joints and increased seepage can lead to increased rates of deterioration and eventual loss of concrete strength.
Efflorescence in itself is not a problem except for the obvious undesirable effect on the concrete appearance. The amount of efflorescence and any increases in this amount over time should be visually evaluated to determine the potential for seepage to affect the integrity of the particular concrete structure.

Efflorescence is usually located near hairline cracks or thin cracks on spillway sidewalls. Efflorescence is usually accompanied by seepage. The seepage can make the concrete more susceptible to freeze-thaw action. In some cases, openings may be sealed against additional leakage by deposits. The deposits may even stop up drain holes and other leakage control features. Efflorescence should be monitored because it can indicate the amount of seepage finding its way through thin cracks in the concrete and can signal areas where problems could develop, such as inadequate drainage behind the concrete or concrete deterioration.

Drummy concrete is concrete with a void, separation, or other weakness beneath the surface, detected by a hollow sound when struck with a hammer, bonker, or other steel tool. Drummy concrete may result in diminished strength of concrete and susceptibility to further deterioration.

Faulty concrete mixes usually result from improperly graded aggregates, improper cement to water ratio, lack of or improper percent of entrained air, inadequate mixing, placing, or curing procedures or equipment, or improper use of additives. A faulty concrete may have a lack of strength, or may be susceptible to deterioration.

Chemical sulfate attack is a reaction between sulfates (calcium aluminate compounds) in soil and ground water with concrete. This type of deterioration may be caused by the use of pre-1930 mix designs that did not consider sulfate attack. The presence of sulfates in local soil or ground water may also be the cause. Sulfate may be derived from natural sources, manufacturing plant wastes, or agricultural runoff contaminating the reservoir water. The concrete usually appears light in color and falls apart easily when struck with a hammer. Other signs of chemical sulfate attack include cracking, spalling, scaling, stains, or total disintegration of the structure or portions of the structure. Type V Portland cement is highly resistant to sulfate attack.

Chemical acid attack is the action of acidic water on calcium hydroxide found in hydrated Portland cement, limestone, or dolomitic aggregates. Acidic water in the reservoir may originate from sewage discharges, coal mine drainage, cinder storage piles, atmospheric gases from nearby industry, industrial wastes, or severe acid rain. Chemical acid attack often leaches away acid-soluble compounds in the concrete, potentially resulting in complete removal of the concrete surface, or a color change of the structure surface. Corrosion and weakening of the reinforcing may also occur, resulting in overstressing of adjacent concrete, which may crack or spall.

Alkali-aggregate reaction results from a chemical reaction between soluble alkali present in cements and certain forms of silica present in some aggregates. The use of marine sediments as aggregates, or shale from river gravels containing cherts often causes alkali-aggregate reactions. This chemical reaction produces byproducts in the form of silica gels which cause expansion and loss of strength within the concrete. Alkali reaction is characterized by certain observable conditions, such as, cracking, usually of random pattern on a fairly large scale, and by excessive internal and overall expansion. Additional indications are a gelatinous exudation and whitish amorphous deposit on the surface, and lifeless, chalky appearance of the freshly fractured concrete. The reaction takes place in the presence of water. Surfaces exposed to the elements or dampened as a result of through dam seepage will demonstrate the most rapid deterioration. Once suspected, the condition can be confirmed by a series of tests performed on cores drilled from the

Table 6-5

Early Indicators of Alkali-Aggregate Reaction

- Pattern cracking, usually in areas exposed to wet-dry cycles, such as:
  - Parapets
  - Piers
  - Top of a dam
- Efflorescence
- Incrustation
- White rings around aggregate particles
- Gel-like substance exuded at:
  - Cracks
  - Pores
  - Openings

Signs of Severe Alkali-Aggregate Reaction

- Disbonding of blocks at lift lines
- Binding of gates
- Severe cracking
- Loss of strength and ultimate failure of the structure
- Swelling

dam. Although the process of deterioration is gradual, alkali-aggregate reaction cannot be economically corrected by any means now known. Continued deterioration often requires total replacement of the structure. Deterioration of concrete from alkali-aggregate reaction may cause abnormal expansion and cracking that may continue for many years. Low alkali Portland cement and fly ash pozzolan can be used in new concrete to eliminate or greatly reduce the deterioration of reactive aggregates.


Figure 6-27 Rebar exposed from spalling is rusting.

Metal corrosion is the formation of iron oxide, or rust, when water (especially salt water) reaches steel in the concrete. It may also be corrosion of aluminum, if used, when water reaches aluminum embedded in or on the concrete. It is often caused by the use of deicing salts on bridge decks and similar structures that can cause corrosion without initial deterioration of concrete. Corrosion typically results in an increase in volume of the reinforcing metal that causes cracking and spalling of overlying concrete (mostly affecting thin structures). Typically, the bond is broken between the steel (or aluminum) and concrete, destroying the structural strength. Visible signs of metal corrosion include straight, uniform crack lines above reinforcing, rust stains on the surface, spalling, exposed reinforcing, and deterioration of concrete adjacent to unprotected aluminum fish ladders, hydraulic pumps, gates, and guardrails.


Figure 6-28 Erosion of concrete on top of riser.

Erosion of concrete is caused by fast-moving water containing abrasive material such as sand and gravel, debris, and ice. Ballmilling is a form of erosion which is the grinding away of a surface, usually in a circular pattern, especially in stilling basins. Erosion results in the wearing away of softer aggregates, or of the matrix material around the aggregates. The inspector should also look for abrasion erosion at points of abrupt change in flow channels or at corners, and the loss of concrete from the surface. Erosion in its worst form may result in severe destruction of concrete.

Erosion due to abrasion results in a worn concrete surface, with polished-looking aggregate. It is caused by the rubbing and grinding of sand and gravel or other debris on the concrete surface of a spillway channel, conduit, or stilling basin. Minor erosion is not a problem but severe erosion can jeopardize the structural integrity of the concrete.

Erosion due to cavitation results in a rough pitted concrete surface. Cavitation is a process in which subatmospheric pressures, turbulent flow and impact energy are created and will damage the concrete. If the shape of the upper curve on the ogee spillway is not designed close to its ideal shape, cavitation may occur just below the upper curve, causing erosion. If the concrete becomes severely pitted, it could lead to structural damage or failure of the structure.

Joint Deterioration - Spillway retaining walls and chute slabs are normally constructed in sections. Between adjoining sections, gaps or joints must be tightly sealed with flexible materials such as tar, epoxies, or other chemical compounds. Sometimes rubber or plastic diaphragms or copper foil is used to seal the joint watertight. During the visual inspection, note the location, length, and depth of any missing sealant. Also, probe the open gap and determine if soil behind the wall or below the slab has been removed by the erosive action of water.

Cavitation, a form of erosion, is the result of the formation of excessive negative air pressures in hydraulic structures. This condition is often caused by offsets or irregularities that produce turbulence. The results are usually pitting and spalling of the flow surfaces. Cavitation may be difficult to identify since it may be similar to other types of deterioration such as abrasion or corrosion of concrete, rock, and metal surfaces. Cavitation is not normally a problem where hydraulic heads are less than 25 feet. If identified, the hydrologic history is important to determine what event may have caused the damage and to evaluate the potential for additional cavitation to occur. Severe cavitation can produce extreme vibrations and erosion which may lead to structural damage and failure. Air vents to flow passages are often used to prevent cavitation; the vents should be examined visually or by pouring water into them to ensure that they are not obstructed.

Cavitation typically occurs downstream of gates and valves, and on steep spillway chutes, tunnels, or conduits. Cavitation creates the potential danger of rapid failure of a spillway or outlet works and that may result in subsequent failure of the dam during large flows.

Surface Defects are other concrete deficiencies that may not be progressive in nature; that is, they do not necessarily become more extensive with time. Surface defects are usually shallow and do not normally present an immediate threat to the structure. However, they may make the concrete more susceptible to more significant deterioration.

Surface defects may include:

- Shallow deficiencies in the surface of the concrete
- Textural defects resulting from improper construction techniques
- Localized damage to the concrete surface

Concrete structures often show signs of some form of deterioration described above.

Spillway entrance floors and walls may exhibit lost lining, scour, and undermining of the structure. The spillway control section floor may suffer from broken slabs, undermining of the structure and exposing the foundation, cracking and spalling, exposed reinforcing, pitting, and scour. Typical causes of these problems include initial construction with poor concrete, high erosive forces, and unbalanced hydraulic pressure against the slab.

The control section pier, walls, and overflow crest may exhibit signs of cracking, spalling, pitting, scour, exposed aggregate, and exposed reinforcing. These deficiencies are commonly the result of poor concrete mixes, chemical attack, erosion, alkali-aggregate reaction, and cavitation.

Table 6-6
Common Surface Defects on Concrete Structures

• **Honeycomb:**	Voids in spaces between coarse aggregate particles.
	Cause - Poor construction practices: segregation due to improper placement or inadequate vibration.
• **Stratification:**	Separation into horizontal layers, with smaller material concentrated near the top. Possible results include nonuniform strength, weak areas, and disbonding of lifts.
	Cause - Overly wet or over-vibrated concrete, poor interlayer consolidation (vibration) or cold joints in placement.
• **Form Slippage:**	Slightly offset blocks, uneven joints and surfaces.
	Cause - Form movement during placement and vibration.
• **Stains:**	Discoloration.
	Cause - Deposits from runoff water, corrosion of exterior steel, spilled construction materials, or curing water with staining qualities.
• **Impact Damage:**	Marred or spalled surfaces.
	Cause - Blows from moving trucks, boats, cranes, or debris.

The discharge channel may exhibit rough patches, loss of concrete, foundation erosion, and exposed reinforcing. These conditions are caused by cavitation due to rough surfaces or irregularities, and erosion from carried debris. Foundation erosion is caused by seepage under the structure.

Common problems in the stilling basin and submerged roller bucket include scour holes more than 6 inches deep in the floor, loss of floor slabs, exposed and damaged reinforcing, and boulders in the basin. These problems are most often caused by inadequate hydraulic jump formation, and gravel or boulders rolling into the basin or bucket.

Figure 6-29 Erosion of foundation soil caused this concrete section to fail.

Non-submerged flip buckets may have visible scour holes (over 12 inches in diameter), blocks of broken concrete, and exposed reinforcing. The usual cause of these conditions includes heavy debris not swept out of the bucket during operation.

Chute blocks or baffle blocks may develop damaged or displaced blocks, and exposed reinforcing caused by cavitation or large rocks or other hard debris in the basin or bucket.

Concrete outlet works usually consist of concrete conduits. These structures may suffer from pattern cracking, pitting, and spalling. The most common cause of this damage is from chemical attack, erosion, cavitation, or deformation due to high loads from earth embankments.

6.5.2.3 Reporting Concrete Deterioration

Condition surveys may be required to help evaluate concrete deterioration. Condition surveys are detailed engineering studies of concrete conditions that include reviews of engineering data, field investigation, and laboratory testing. If a condition survey was performed on a dam or its appurtenant structures, the survey should provide a basis for assessing the concrete deficiencies that may be encountered.

Surface mapping involves documenting concrete defects in a systematic manner. All types of concrete deterioration should be included. Surface mapping generally consists of developing a detailed record of the cracks on paper or on film so that future changes can be monitored. The mapping can be accomplished using detailed drawings, photographs, or videotape to record the current features and deficiencies. When photographs are used, a ruler or familiar object should be included to indicate scale. A grid is sometimes used to overlay a section of a drawing so the location of cracks and other defects can be shown easily.

If differential movement at joints or stress concentrations could have been responsible for damage, the inspector should review Instrumentation or measurement data for evidence of these conditions, or recommend that additional instrumentation be Installed to monitor the affected area.

If deterioration is observed during a visual inspection of a concrete spillway or outlet, the inspector should take the following actions:

- Photograph and record location, type, and extent of the deterioration. Note prominent features, and whether cracking is also present.
- Look for structural damage, including misalignment, settlement, vertical and horizontal displacement.
- Look for any surrounding damage to structures or foundations.
- Classify and describe the deterioration using the terminology defined earlier.
- If deterioration is extensive, consider initiating a condition survey or surface mapping to thoroughly document all problems in the structure and their characteristics. Contact a qualified dam safety professional if there is uncertainty about the severity of deterioration.
- Look for evidence of seepage or saturated soils in or below the structures. Also look for signs of foundation soil erosion. If there is an excessive amount of

water, or water which cannot be handled by the drainage system is flowing through a crack, recommend repairs. Check with a concrete specialist to identify appropriate repair procedures.

- Determine if other dam structures, such as the embankment, could be affected by the deterioration in the spillway or outlet.
- Closely monitor the problems for changes.
- Try to determine the cause of the deterioration; this can help identify effective corrective actions.
- Consult a qualified dam safety professional to determine the cause of the problem if it is severe or gets progressively worse. Serious deterioration or repair operations may require lowering the reservoir level.
- Recommend appropriate corrective action be taken to repair or to replace the damaged spillway or outlet areas. The recommended corrective actions should be consistent with the inspector's training and experience.

6.5.3 Metal Structures and Materials

Figure 6-30 Soil erosion under this metal spillway caused the outlet end to settle, resulting in the inlet end tilting upward.

A number of metal structures serve functions in dams and appurtenances. These structures may include metal gates and valves, conduits, cranes and hoists, and operating and access bridges. Some of these structures must maintain their operability to ensure the safety of the dam. Metal structures often serve as part of the outlet works that controls reservoir levels and releases excess flows, and so are especially crucial to dam safety. The failure of metal structures could form obstructions that would endanger the dam.

Figure 6-31 This corrugated spillway pipe rusted through, allowing seepage to enter the pipe.

Corrugated metal pipes that are used as spillway structures can have other serious problems besides corrosion. These problems are usually associated with installation practices, and include foundation or backfill erosion, and pipe buckling and crushing. These problems are usually caused by poor compaction in the haunching zone, poor compaction of backfill material beside and over the pipe, and heavy equipment traffic over the pipe. Because of these problems, corrugated metal pipes are not recommended for initial placement, upgrades, or replacements in any dam.

Metal suffers more damage from corrosion than from any other deficiency. Most metal deficiencies are types of corrosion, are related to corrosion, or eventually will involve corrosion. Coatings prevent or delay corrosion in metal. Failure of a coating, therefore, may result in failure of the metal structure due to corrosion. Corrosion is an electrochemical reaction and has been defined by the National Association of Corrosion Engineers as "the deterioration of a material, usually a metal, by reaction with its environment." The inspector should be able to recognize the types and hazards of metal corrosion, and distinguish hazardous metal corrosion from corrosion that is just a maintenance problem.

Destruction of metal parts obviously occurs by processes other than corrosion (e.g., abrasion, fatigue); however, these processes are often accompanied by corrosion of varying intensity. Corrosion may be widespread over the surface of a structure resulting in relatively uniform loss of metal, or it may be highly localized, resulting in pitting of the surface and possible penetration of the metal. Either form may be destructive, depending upon the operating requirements of the structure.

6.5.3.1 Corrosion

Corrosion is a common problem of pipe spillways and other conduits made of metal. Exposure to moisture, acid conditions, or salt will accelerate the corrosion process. Pipes made of non-corrosive materials such as concrete or plastic should be used in new dam construction, or in dam rehabilitation.

Corrosion of any metal component should be identified since it can weaken metal parts, decrease wall thicknesses, and hinder operation of mechanical equipment. This identification should cover mechanical equipment, gates, valves, pipe spillways, lake drains, internal drain pipes, and other structural steel elements.

Frequently, corrosion is a significant problem with metal conduits, pipe and riser spillways, and drains. The type of pipe (smooth steel, corrugated metal, ductile iron, etc.), the protective coating or corrosion protection system, and the wall thickness of the metal are factors which determine the corrosion rate and significance. Seepage around a metal pipe at the outlet end may be an indicator of corrosion if joints are known to be watertight. Both water quality and soil conditions are other factors affecting the rate of metal corrosion. Metal conduits through embankment dams need to be examined with special care for signs of corrosion. Corrosion holes and perforations could allow water into the surrounding embankment from the conduit, or into the conduit from the embankment. Either of these situations can result in piping through the embankment.

Corrosion of mechanical parts such as valve stems and guides could prevent operation of a drain or gate system in an emergency. A gate or valve broken during operation can also result in the unexpected draining of the impoundment and the danger of a sudden drawdown, which could trigger earth slides. Inspecting personnel should be alert and try to identify the most likely cause of corrosion. Design errors, poor maintenance, severe weather conditions or a change in water quality could be contributing factors.

Corrosion may manifest itself in a number of different ways. For discussion, it is convenient to use the “eight forms of corrosion" as described by Fontana and Greene in Corrosion Engineering. These eight forms are described below.

(1) Uniform Attack - The most common form of corrosion. Proceeds uniformly over a large area. Results in uniform thinning of the surface and eventual failure if not controlled.
(2) Galvanic or Bimetal Attack - Formed when different metals from the galvanic series are coupled. Corrosion is predictable according to the galvanic series.
(3) Crevice Corrosion - Often intense and localized. May occur under gaskets, within lap joints, under surface deposits, mud, or other detritus.
(4) Pitting Corrosion - Intense, highly localized corrosion resulting in holes of relatively small diameter and large depth. May result in penetrations and leaks.
(5) Intergranular Corrosion - Most often noted in or near improperly executed welds in stainless steels. May appear as "knife line" corrosion (as if the metal has been slit) or as thinning of the material in the heat-affected zone adjacent to the weld.
(6) Selective Leaching - The removal of one material from a solid alloy by corrosion. In cast iron, the removal of iron from the alloy, leaving only the carbon matrix (graphitization). In brasses, the removal of aluminum or zinc from the alloy (de-alumification or dezincification). In either case, the remaining material has little strength.
(7) Erosion Corrosion and Cavitation - Deterioration of metals because of high velocity impingement on the surface. Results in directional pits and grooves.
(8) Stress Corrosion - Often results in cracking of highly stressed materials (bolts, for example) in corrosive or mildly corrosive environments. Failure can be unanticipated and catastrophic. Stress corrosion cracking can also occur in improperly heat treated metals. The failure of the component could be at a load that is much less than the intended design.

Common methods of protecting metals from corrosion include protective coatings (paint) and cathodic protection. A third method is used in the design process by incorporating, in the construction, materials that are immune from corrosion in the particular environment expected. Unfortunately, except for occasional replacement of parts, this method is unavailable to the operator of an existing structure.

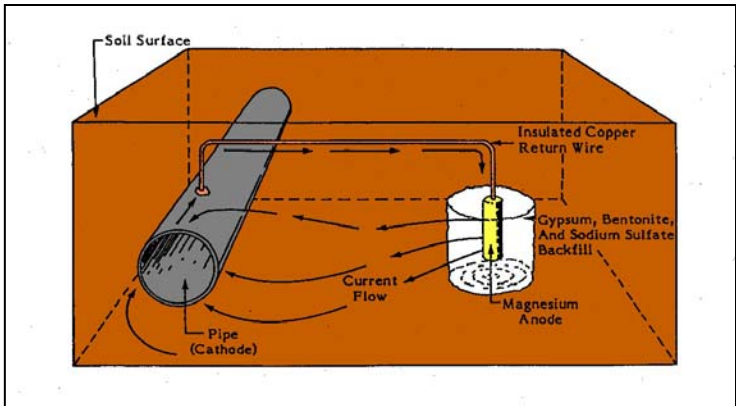


Figure 6-32 Illustration of cathodic protection of buried a metal pipe.

Metal pipes are available which have been coated to resist accelerated corrosion. Coatings can be of epoxy, aluminum, zinc (galvanized), polymers, or asbestos. Coatings applied to pipes in service are generally not very effective because of the difficulty in establishing a bond. Bituminous coatings cannot be expected to last more than one or two years (in flowing water.

Corrosion of metal can also be controlled or arrested by installing cathodic protection (see Figure 6-32). A metallic, sacrificial anode such as magnesium, zinc, or aluminum is buried in the soil and is connected to the metal pipe by wire. Degradation of the anode produces an electrical current that flows from the magnesium (anode) to the pipe (cathode) and will cause the magnesium to corrode and not the pipe. Another method of cathodic protection consists of the impressed current system. An impressed current system includes a rectifier that converts an alternating power supply to a direct current that is properly calibrated to provide the required protection. Since the power source is delivered to the anode and is not generated by its degradation, the impressed current system can be calibrated to meet the site's conditions. Current can be automatically and continuously adjusted to meet varying conditions. Voltage provided by sacrificial anodes is too high when new and too low when old, so the impressed current system provides a means for supplying the right amount of current at all times. However, the best way to avoid corrosion in spillway conduits is to not use metal pipes.

Table 6-7
Likely Sites for Corrosion

- Missing or damaged protective coatings

- Areas where metal has been rolled to shape rather than cast, or has been bent or distorted, including:

    - Angle supports
    - Rolled plates
    - Distortions from riveting Welded areas
    - Parts misaligned during assembly

- Contacts between dissimilar metals causing galvanic corrosion, including:

    - Gate arms, connections, and chains of incompatible metals
    - Steel screws in brass
    - Lead solder around copper wire
    - Steel shaft rotating in bronze bearings
    - Broken rust or mill scale (iron oxide) allowing galvanic reaction with exposed steel
    - Dissimilar metals embedded in concrete, such as aluminum conduit and steel reinforcing (aluminum should not be embedded in concrete)

- Sites where moisture and limited oxygen supply on the metal surface create conditions for galvanic corrosion, including:

    - Under accumulations of dirt or other surface contaminations
    - In crevices (crevice corrosion) such as joints and cracks, rivet holes, gaskets, and valve seats
    - Under coatings (underfilm corrosion destroys coating integrity, allowing corrosion to accelerate)

- Areas of high velocity flows, such as in pressurized sections of conduit, downstream from gates and valves, on needle and tube valves, on outlet pipes in the vicinity of gates, and in locations of sudden changes of direction or flow cross-section

- Locations where metal is cracked due to tensile or dynamic stress, such as in gates, gate seal bars, gate and bridge supports, metal flashboards and stop logs, valves, valve stems, gate and valve operators, and moving parts on cranes and hoists such as rods and connecting pins

- Buried conduits, including joints where new sections of conduit were inserted adjacent to older sections

Corrosion of metal parts of operating mechanisms may be effectively treated and prevented by keeping these parts greased and/or painted. The inspector should look for these signs of preventive maintenance, and recommend that they be implemented if not currently used.

Most of the metal corrosion that the inspector observes during a visual inspection will probably be a maintenance concern only. He/she should be able to recognize when corrosion is a potential safety issue that threatens the safety of the dam.

Some structures are especially crucial to dam safety. Metal corrosion becomes hazardous when it renders critical metal structures inoperable. Inoperable gates, valves, or cranes and hoists endanger a dam when the ability to release flood flows is hindered and the dam is in jeopardy of being overtopped. Corrosion that is not particularly severe or extensive may interfere with operation or bind moving mechanical parts.

Metal girders used as supports for an operating or access bridge might buckle if weakened by extensive corrosion and preclude access to gate or valve controls. Inability to operate spillway gates during a flood could cause the dam to overtop.

Pitting can perforate a metal conduit and allow water to erode an embankment dam from within. Pay careful attention to areas where coating is missing or defective. A very small opening in a coating can result in severe, concentrated corrosion at that spot.

Test the operation of gates and valves at regular intervals and during any formal technical inspection. Testing operation is the best way to determine if corrosion is hindering the proper functioning of these devices (the owner should perform all testing).

If the inspector observes metal corrosion, he/she should:

- Photograph and record location, type, and extent of the deterioration. Note prominent features, and whether other damage is also present.
- Look for structural damage, including misalignment, settlement, vertical and horizontal displacement.
- Look for any surrounding damage to structures or foundation.
- Classify and describe the corrosion using the terminology previously defined.
- Consult a corrosion specialist if:

  (1) Hazardous metal corrosion may endanger the dam either because the corrosion site is sensitive to relatively small degrees of corrosion (as in a mechanical device such as a gate) or because the corrosion is severe and extensive enough to cause a metal structure to fail.

  (2) It is suspected that metal has been lost to corrosion on an inaccessible surface, such as the outside of buried metal conduit. Ultrasonic thickness measuring equipment operated from the opposite side can estimate metal thickness, but the extent of pitting corrosion is difficult to determine because damage tends to be highly localized. The conduit may need to be excavated for thorough examination.

- Evaluate pitting, a common form of corrosion, by counting the number of pits (if sites are few) or by using a system of rating charts, which are based on the

percentage of pitted area.
- Document all observations and recommend corrective action and timing.

6.5.3.2 Cracking and Deformation

Cracking in metal is a separation into two or more parts, while deformation is the bending or twisting of a metal object into other than its design shape.

Metal cracking and deformation tend to afflict mechanical devices, such as cranes and hoists, or structures subjected to static and dynamic stress, such as gates and valves. Uneven hoist pull is a possible cause for gate frame and lifting beam distortion, broken gate connections, and broken lifting chain or wire rope. Deep or extensive cracking indicates that failure due to tearing and rupture may be imminent, while deformations may interfere with mechanical operations. During flooding or other emergencies, inoperable equipment could endanger a dam by being unable to release flood flows.

Metal cracking and deformation usually include three types of deficiencies: (1) cracking and stress corrosion cracking; (2) fatigue and corrosion fatigue; and (3) overload failure.

Cracking and corrosion in metals may be closely related; stress corrosion cracking and corrosion fatigue involve both corrosion and mechanical forces. Stress corrosion cracking results from a combination of tensile stress and a mildly corrosive environment. The inspector should look for signs of stress under corroded areas to determine if there was a mechanical force involved that caused fatigue of the metal.

Fatigue is loss of metal strength from repetitive bending, known as corrosion fatigue when combined with corrosion. The affected area weakens, cracks, and then tears or ruptures. Sharp notches and reentrant corners without fillets are often points (called "stress risers") where a crack starts.

An overload failure results from a single stressing beyond the tensile, shear, or compression strength of a metal part. An example is a conduit or liner buckling due to an internal vacuum or external pressure.

During dam safety visual inspections, the inspector probably will observe far more corrosion than cracking and deformation of metals. Cracking and deformation

Table 6-8
Likely Sites for Metal Cracking and Deformation

- Gates
  - Gate connections
  - Gate side guides
  - Lifting lugs or attachments
  - Lifting chain or wire rope
    - ■ Kinks in wire rope
    - ■ Failure at bends in wire rope
    - ■ Defective plastic coating on wire rope
    - ■ Failure at connections
  - Roller train components (tractor gates)
  - Vanes supporting hollow-cone valves
  - Gates
  - Lifting beams
- Conduits
  - Welded joints
  - Fittings
  - Conduit lining
  - Conduit coating
  - Conduit

Measure conduit height and width to detect "egg-shaped" or oval conduit flattened by heavy loads. Look for cracks in the conduit, the lining, and the coating caused by stress concentrations.

usually affect the integrity of a metal part, and therefore are likely to be hazardous to the safety of a dam.

If the inspector observes metal cracking or deformation that may affect the safety of the dam, he/she should:

- Photograph and record the extent, location, and possible causes of cracks and deformations.
- Compare observations with prior inspection reports
- Consult a qualified dam safety professional for further evaluation and proposed corrective measures.

6.5.3.3 Metal Coatings

Metal coatings are coating systems that have been specifically formulated to adhere to metal (or other materials) and protect it from corrosion. Metal coating systems for dams and associated structures (penstocks, power plants, administrative and maintenance structures, etc.) can be divided into four general categories:

(1) Coating systems that will be fully immersed in water or covered with backfill (buried)
(2) Coating systems that will be both immersed in water and subjected to atmospheric exposure
(3) Coating systems that will receive exterior atmospheric exposure only
(4) Coating systems that will receive interior atmospheric exposure only

Some coating systems overlap one or more of the above categories. Although it is possible that exposure to severe chemicals, saltwater, severe chemical fumes, or salt spray could be encountered, and a coating system that would resist these types of exposure would be required, it is not likely that such exposure conditions would be experienced with freshwater dams and dam-related structures in Indiana.

Coating systems control corrosion in one or more of the following ways:

- Creating a barrier between the metal and corrosive agents in the environment. It is important to realize that there is no such thing as a completely and indefinitely impervious coating system.
- Gradually releasing corrosion-inhibiting chemicals.
- Sacrificial action in which the sole or major component of the coating, such as zinc, sacrifices itself to protect the metal underneath. The coating in effect provides a kind of cathodic protection.

Defective or missing protective coatings expose metal parts and structures to corrosion and, therefore, to ultimate failure. Failure of metal structures such as gates, bridges, and conduits can result in dam failures.

All coatings systems fail prematurely for one or more of the following reasons:

- Poor surface preparation (very frequent cause)
- Poor application procedures (frequent cause)
- Improper specification of a coating system for the underlying metal or exposure conditions it will be facing in the field (infrequent cause)
- Defective or off-standard coating system materials as a result of mistakes or contamination during their manufacture (infrequent cause)
- Physical or mechanical damage, resulting from impacts, cavitation, or erosion from water carrying abrasive sediment

Identifying and quantifying metal coating system deficiencies is accomplished by periodic visual inspection of the applied coatings. This inspection is relatively easily accomplished on the coating systems that are exposed to the atmosphere, either indoors or outdoors, and are reasonably accessible. Visual inspections of immersed coating systems on gates, the interiors of penstocks, etc., can be accomplished only when those structures have been dewatered. Buried coating systems on the exteriors of pipe or other structures cannot be directly inspected unless they have been uncovered for some reason. If there is a corrosion monitoring system in place, the coating systems can be indirectly inspected for their general conditions. Among the tools required for the visual inspections are: a knife, a magnifying glass, and a thickness gauge. A pit gage or other means of measuring, or at least reasonably estimating, the depth of pits is also necessary.

The first areas to exhibit coating failure are usually welds, bolt heads, edges, and areas where access is difficult. The thickness gauge is used to measure decreases in coating system thickness from erosion, chalking, and abrasion. Thicknesses are usually measured in thousandths of an inch (mils). (As a point of comparison, a dollar bill is about 4 mils thick.) Pitting is often the most serious defect and can cause rapid failure of piping or other structures while a major portion of the remaining metal is intact. This defect can be very serious in a metal conduit running through an embankment dam, for example, because the escaping water can erode the dam from within. Measuring the depth of pits enables a calculation to be made of the pit depth versus the thickness of the steel.

A knife is one of the best and most important inspection instruments for checking corrosion and pitting. It is necessary for removing corrosion so that pitting can be measured, and for removing loose coating system material so that corrosion undercutting of the coating system film can be discovered. A knife is a good instrument for checking adhesion to see how much adequately bonded coating is left if there is local peeling or other signs of removal of the coating system. It can also be used to check flexibility and discover embrittlement of coating system films, and to break blisters to check the condition of the metal underneath.

Quantification of coating system defects can be accomplished by using ASTM pictorial methods. These methods are available in *Pictorial Standards of Coating Defects* published by the Federation of Societies for Coatings Technology (FSCT). Pictorial standards are available for blistering, chalking, checking, cracking, erosion, filiform corrosion, flaking, mildew, and rusting. Both a number and a description are given, such as No.4-medium dense blisters. Through the use of these standards it is possible to convey the appearance of a coating system defect to people who have not witnessed it personally. It is very important to accurately record the locations of defects. An imaginary grid system can be used as long as the location of the grids is recorded. Another method is verbal description, such as upper left or center left of a gate whose dimensions are given. In pipes the distance and direction from reference points, such as the pipe outlet or manholes, can be given.

Recording the results of both scheduled and unscheduled coating system visual inspections is extremely important. The records of the coating systems on all structures must begin with the coating systems that were originally applied. A complete history must be kept of all the coating systems that have been applied to the structures, including records of touchups. An existing system must be over coated or touched up with a compatible coating. The records can track the rate of deterioration of coating systems and make pre-planned maintenance and recoating possible. Also, the records can supply the information required for decisions on whether to touch up, repair and overcoat, or remove the existing coating system to metal, prepare the surface, and completely recoat with the same or a different coating system.

6.5.3.4 Cavitation

Cavitation damage can be detected visually in areas where cavitation is likely to occur. It is distinguished by the loss of material in a pitting pattern which appears as though the lost material was "sucked" off or, in some instances, by removal of the coating system and evidence of attack on the metal underneath.

Cavitation is likely to occur at the same locations in metal pipes as in concrete pipes, as described earlier. Cavitation may be reduced by introducing air through a vent pipe at a point downstream of the control valve, where a pressure drop is expected. The vent pipe establishes atmospheric pressure so that a partial vacuum is not created, and cavitation is avoided.

Cavitation is also found on valve surfaces.

6.5.4 Conduit and Pipe Special Concerns

This subchapter provides more specific information on spillway and outlet conduits and pipes in addition to the other information presented earlier.

Many dams have conduit systems that serve as principal spillways and outlets. These conduit systems are required to carry normal stream and flood flows safely past the

Figure 6-33 Inspecting a spillway that has flowing water is very difficult.

embankment throughout the life of the structure. Conduits through embankments are difficult to construct properly and can be extremely dangerous to the embankment if problems develop after construction. Conduits are usually difficult to inspect and repair because of their location within the embankment. Also, replacing conduits requires extensive excavation. In order to avoid difficult and costly repairs, particular attention should be directed to maintaining these structures. The most common problem noted with spillway conduit systems is undermining of the conduit. This condition typically results from water leaking through pipe joints, seepage along the conduit or inadequate energy dissipation at the conduit outlet. The typical causes of seepage and water leaking through pipe joints include any one or a combination of the following factors: loss of joint material, separated joints, misalignment, differential settlement, conduit deterioration, and pipe deformation. Problems in any of these areas may lead to failure of the spillway system and possibly dam failure.

Figure 6-34 The outlet of this spillway has been undermined from the erosive forces of the discharge water.

Undermining is the removal of foundation material surrounding a conduit. Any low areas or unexplained settlement of the earthfill in line with the conduit may indicate that undermining has occurred within the embankment. As erosion continues, undermining of a conduit can lead to displacement and collapse of the pipe sections and cause sloughing, sliding or other forms of instability in the embankment. As the embankment is weakened, a complete failure of the conduit system and, eventually the dam may occur. Undermining along the entire length of conduit is referred to as piping.

In addition, undermining can occur as the result of erosion due to inadequate energy dissipation or inadequate erosion protection at the outlet. This undermining can be visually observed at the outlet of a pipe system and can extend well into the embankment. In this case, undermining can lead to other conduit problems such as misalignment, separated joints and pipe deterioration.

The inspector should look for signs of undermining and piping, including sinkholes, water seepage, loss of pipe-joint material, sediment build-up at the outlet, and movement of pipe sections.

Seepage along the conduit from the reservoir can occur as a result of poor compaction around the conduit. If seepage control devices have not been installed, the seepage may remove foundation material from around the conduit and eventually lead to piping. Seepage is usually easy to spot around conduits.

Pipe deformations are typically caused by external loads that are applied on a pipe such as the weight of the embankment or heavy equipment. Collapse of the pipe can cause failure of the joints and lead to erosion of the supporting fill. This may lead to undermining and pipe settlement. Pipe deformation may reduce or eliminate spillway capacity. Pipe deformation must be monitored on a regular basis to ensure that no further deformation is occurring, that pipe joints are intact and that no undermining or settlement is occurring. A common cause of pipe deformation is inadequate compaction of fill under and around the conduit.

Conduit systems usually have construction and/or section joints. In almost every situation, the joints will have a water stop, mechanical seal and/or chemical seal to prevent leakage of water through the joint. Separation and deterioration of the joints can destroy the watertight integrity of the conduit system. Joint deterioration can result from weathering, excessive seepage, erosion or corrosion. Deterioration at joints includes loss of gasket material, loss of joint sealant, and spalling around the edges of joints. Separation at a joint may be the result of a more serious condition such as foundation settlement, undermining, structural damage, or structural instability. Separated pipe joints can be detected by inspecting the interior of the conduit. Both separation and deterioration of joints allow seepage through the conduit. The seepage can erode the fill underneath and along the conduit causing undermining, which can lead to the displacement of the pipe sections or embankment piping. A visual inspection program is needed to determine the rate and severity of joint separation and deterioration. Joint separations should be monitored on a regular basis to determine if movement is continuing.

Deterioration of conduit material is normally due to the forces of nature such as wetting and drying, freezing and thawing, oxidation, decay, ultra-violet light, cavitation, and the erosive forces of water. Deterioration of pipe materials and joints can lead to seepage through and along the conduit and eventually failure of conduit systems.

Removal or consolidation of foundation material from around the conduit can cause differential settlement. Inadequate compaction immediately next to the conduit system during construction may compound the problem. Differential settlement can ultimately lead to undermining of the conduit system or embankment piping. Differential settlement should be monitored with visual inspections and documentation of observations.

Alignment deviations can be an indication of movement, which may or may not be in excess of design tolerances. Proper alignment is important to the structural integrity of conduit systems. Misalignment can be the direct result of internal seepage flows that have removed soil particles or dissolved soluble rock. Misalignment can also result from poor construction practices, collapse of deteriorated conduits, decay of organic material in the dam, seismic events, or normal settlement due to consolidation of embankment or foundation materials. Excessive misalignment may result in other problems such as cracks, depressions, slides on the embankment, joint separation, and seepage. Both the vertical and horizontal alignment of the conduit should be inspected on a regular basis.

All conduits should be inspected thoroughly once a year as part of the maintenance inspection program. Conduits that are 30 inches or more in diameter can be entered and visually inspected with proper ventilation and confined space precautions. Small inaccessible conduits may be monitored with video cameras. The conduits should be inspected for misalignment, separated joints, loss of joint material, deformations, leaks, differential settlement, and undermining. Problems with conduits occur most often at joints, and special attention should be given to them during the visual inspection. The outlet should be checked for signs of water seeping along the exterior surface of the conduit. Generally, this is noted by water flowing from under the conduit and/or the lack of foundation material directly beneath the conduit. The embankment surface should be monitored for depressions or sinkholes. Depressions or sinkholes on the embankment surface above the spillway conduit system develop when the underlying material is eroded and displaced. The inspector should photograph all problems that are observed in the conduits.

Accessible portions of conduits, such as the outfall structure and control, can be easily and regularly inspected. However, several problems are commonly associated with deterioration or failure of portions of the system which are either buried in the dam or normally under water. The following are some general guidelines for inspecting conduits:

- Conduits that are 30 inches or greater in diameter can be inspected internally, provided the system has an upstream valve, allowing the pipe to be dewatered. Tapping the conduit interior with a hammer will help locate voids which may exist behind the pipe. This type of inspection should be performed at least once a year during maintenance inspections.
- Small diameter pipes can be inspected by remote TV camera. The camera is moved through the conduit and transmits a picture to an equipment truck, where it can be viewed by a technician. This type inspection is expensive and usually requires the services of an engineer. However, if no other method of visual inspection is possible, the use of TV equipment is recommended at least once every five years.
- Outlet intake structures, wet wells, and outlet pipes with only downstream valves, are the most difficult to inspect because they are usually under water. These should be scheduled for visual inspection when the reservoir is drawn down or at five year intervals. If a definite problem is suspected, or if the reservoir remains full over extended periods, divers should be hired to perform an underwater inspection.

6.5.5 Testing the Outlet System

Dam drawdown valves and outlets must be operationally tested on an annual basis, between November 1 and March 30, before the onset of the flood season (typically March in Indiana) to verify their performance and to help keep them in operating order. Unused outfall valves and controls can become corroded or blocked with sediment, so routine testing can help maintain these devices. In order to verify that the valve is still functioning, but to minimize the quantity of silt and/or poor quality water that may be released downstream, the following procedure is to be used:

(1) The area immediately in front of the drawdown structure shall be checked for debris that might be drawn into the opening, and cleared of such debris as much as possible. If there is reason to believe that there may be silt immediately in front of the opening at an elevation equal to the invert or higher, the structure shall not be tested until such silt is removed, complying with all regulatory requirements prior to doing so.

(2) The structure shall be opened a minimal amount, enough to allow a flow, and then closed fully, to verify ability to operate in that direction.

(3) The structure shall then be fully opened, and immediately closed again, minimizing the open period as much as possible.

(4) If there is any sign of erosion occurring downstream during the process, the operation shall be halted and the structure closed. Remedial actions shall be taken to prevent erosion from the flows prior to the test being repeated or completed.

(5) If the valve fails to fully close, either in step two or step three, an emergency contractor and a dam safety engineer should be immediately notified.

The outlet system should be checked through the full range of gate settings. Slowly open the valve, checking for noise and vibration. Certain valve settings may result in greater turbulence. Check for noise that sounds like gravel being rapidly transported through the system. This sound indicates that cavitation is occurring. Note the operating range that produces this noise, and, if possible, avoid operating under these gate settings. Check the operation of all mechanical and electrical systems associated with the outlet. Backup electric motors, power generators, and power and lighting wiring should function as intended and be in a safe condition.

The outlet, or lake drain, should always be operable so that the pool level can be drawn down in case of an emergency or for necessary repair. Lake drain valves or gates that have not been operated for a long time present a special problem for owners. If the valve cannot be closed after it is opened, the impoundment could be completely drained. An uncontrolled and rapid drawdown could also induce more serious problems such as slides in the saturated upstream slope of the embankment. Drawdown rates should not exceed 1 foot per day for slopes of clay or silt material except for emergency situations. Very flat slopes or slopes with free-draining upstream zones may be able to withstand more rapid drawdown rates; however, the owner should consult with IDNR or a qualified dam safety professional before using a more rapid drawdown rate. Large discharges could also cause downstream flooding. Therefore, before operating a valve or gate, it should be inspected and all appropriate parts lubricated and repaired. It is also prudent to advise downstream residents of large and/or prolonged discharges.

To test a valve or gate without risking that the lake will be drained, the inlet upstream from the valve must be blocked. Some drain structures have been designed with this capability and have dual valves or gates, or slots for stoplogs (sometimes called bulkheads) located upstream of the drain valve. Divers can be hired to inspect the drain inlet, and may be able to construct a temporary block at the inlet for testing purposes. Early detection of equipment problems or breakdowns, and confidence in equipment operability, are benefits of periodic operation.

Sediment is another problem that may be encountered when operating the lake drain. Sediment deposits can build up and block the drain inlet. Debris can be carried into the valve chamber, hindering its function if an effective trash rack is not present. The potential that this problem will occur is greatly decreased if the valve or gate is operated and maintained periodically.

Many older dams have drains with valves at the downstream end. If the valve is located at the downstream end of a conduit extending through the embankment, the conduit is under the constant pressure of the reservoir. If a leak in the conduit develops within the embankment, saturation, erosion, and possibly failure of the embankment could occur in a short period of time. A depression in the soil surface over the pipe may be a sign soil is being removed from around the pipe. These older structures should be monitored closely and owners should plan to relocate the valve upstream or install a new drain structure. Inspectors should closely examine the drain outlet for signs of possible problems when valves are located at the downstream end of the drain.

6.5.6 Mechanical Equipment

Mechanical equipment includes spillway gates, sluice gates or valves, stoplogs, sump pumps, flash boards, relief wells, emergency power sources, siphons and other equipment associated with spillways, drain structures, and water supply structures. Stoplogs, flashboards, and siphons are not necessarily mechanical equipment, but are included in this category because they could be, and the equipment used to implement them usually is. Mechanical and associated electrical equipment should be checked for proper lubrication, smooth operation, vibration, unusual noises, and overheating. The adequacy and reliability of the power supply should also be checked during operation of the equipment. Auxiliary power sources and remote control systems should be tested for adequate and reliable operation. All equipment should be examined for damaged, deteriorated, corroded, cavitated, loose, worn, or broken parts.

Gate stems, guides, and couplings should be examined for corrosion, loose, broken or worn parts, and damage to protective coatings. Fluidways, leaves, metal seats, guides, and seals of gates and valves should be examined for damage due to cavitation, wear, misalignment, corrosion, and leakage. Sump pumps should be examined and operated to verify reliability and satisfactory performance. Air vents for pipes, gates and valves should be checked to confirm that they are open and protected. Wire rope or chain connections at gates should be examined for proper lubrication and worn or broken parts. Rubber or neoprene gate seals should be examined for deterioration or cracking.

Hydraulic hoists and controls should be checked for oil leaks and wear. Hoist piston and indicator stems should be examined for contamination and for rough areas that could damage packings.

Many dams have structures above and below ground that require some type of access. Water supply outlet thimble works, lake drains, gated opening spillways, drop box spillways, and toe drain manhole interceptors are typical structures that will require bridges, ladders, or walkways. Care should be taken to properly design, install, and maintain these means of access for the safety of persons using them. Access requirements for walkways may include toe plates and handrails. Fixed ladders should have proper rung spacing and safety climbing devices, if necessary. Access ladders, walkways, and handrails should be examined for deteriorated or broken parts or other unsafe conditions.

Stoplogs, bulkhead gates, and lifting frames or beams should be examined to determine their availability and condition. The availability, operability, and locations of equipment for moving, lifting, and placing stoplogs, bulkheads, and trash racks should also be verified.

Figure 6-35 Wood flashboards exhibiting leakage.

Flashboards are usually wood boards installed in an upright position along the crest of the spillway to raise the normal pool level. Flashboards should not be installed or allowed unless professional investigation indicates there is sufficient freeboard remaining to safely pass the design flood. Some flashboard installations are designed to fail when subjected to a certain depth of flowing water, thereby recovering the original spillway capacity. However, flashboards designed to fail may not be reliable and are not recommended. Maintenance generally consists of repairing or replacing broken boards. The support structure for the flashboards should be examined for damage due to wear, misalignment, corrosion, and leakage, and repaired as necessary. The flashboards should be removed periodically (at least once a year) as a check for freedom of movement and deterioration of the boards. Leakage is a common problem. Unless there are extenuating circumstances, flashboards should be removed prior to the onset of flood season (typically March in Indiana) and reinstalled when conditions permit.

6.5.7 Earth and Rock Materials

6.5.7.1 Earth Spillways


Figure 6-36 Severe erosion in earth outlet channel adds sediment to receiving stream.

When inspecting an earth spillway, the inspector should determine whether side slopes have sloughed, or whether there is excessive vegetative growth in the channel. The entrance and exit of the spillway should be unobstructed by trees, brush, or general vegetative overgrowth; during severe flooding, accumulation of drift in these areas can significantly reduce spillway capacity, increase erosion and contribute to overtopping of the dam and possible failure. The inspector also should look for signs of erosion and rodent activities. Use a probe to obtain a comparative feel of the hardness and moisture content of the soil. Note the location of particularly wet or soft spots. See if the stilling basin or drop structure is properly protected with rocks or riprap. Since some erosion is unavoidable during discharge of water, determine whether such erosion might endanger the embankment. If the spillway is installed with a sill, determine if there is any cracking or misalignment of the sill. Also look for any erosion beneath or downstream of the sill.

If spillway side walls slide and block the spillway entrance or channel, the dam may become susceptible to overtopping because of reduced capacity to pass flood flows. Erosion of plunge pools and return channels may expose the toe of the dam to erosion, undercutting, and subsequent slope failure.

6.5.7.2 Rock Cuts


Figure 6-37 Spillway constructed in a rock cut.

Dams built in areas where rock is at or near the surface may include outlet works and spillway channels and tunnels constructed in or through the rock. Fallen rock may block discharges through a tunnel or channel, or rock falling into the reservoir immediately upstream from the dam could render outlet works, penstocks, or spillways inoperable. Abutment movement may restrict or prevent operation of appurtenances located in or on the abutment. Loosened rock could block or damage structures in their fall paths. Any of these conditions may cause the dam to be overtopped.

Rock deficiencies can be described by one of the following categories:

- Inadequate hardness or strength
- Discontinuities (faults, shears, joints, bedding planes)
- Weathering, or deterioration (temperature variations (thermal stresses), freeze-thaw action, erosion, plant and animal activity, chemical action)
- Solutioning (chemical weathering of mineral or rock into solution by seepage flow)

Excavated rock slopes and tunnel walls are subject to spalling and weathering from freeze-thaw action. Rock contains joints (also called fractures or discontinuities) along which water can pass, resulting in deterioration. Movement at these joints caused by an earthquakes or excess hydrostatic pressure may result in large rock falls.

The inspector should be alert for potentially large rock falls, slides, and resulting obstruction of tunnels and spillway channels. These potentially hazardous conditions are typically caused by instability of rock slopes, degradation of rock slopes, seepage from cut faces, and deficient rock reinforcement.

Slope instability in rock spillways usually results in slides or movement on the slopes. Look for signs of rock movement at fractures and joints which might indicate a future rock fall or slide. Movement is often indicated by fresh cracks on the rock surface, cracks in dam concrete where it joins the rock, blocks falling from abutments, displacement of vegetation, and arc-shaped cracks on or above slopes. Slides on slopes adjacent to spillways are especially hazardous because of the potential for blockage, or damage to the structure preventing operation. In rock abutments adjacent to a concrete dam, look for freshly exposed rock at or near the dam-abutment contact. Check any instrumentation data that may exist for indications that rock walls or slopes have moved. Movement of abutment rock can be very serious, possibly resulting in loss of support for the dam. If data show progressive movement and increasing seepage pressure, the dam and abutments may be in danger of destabilization.

Degradation of rock slopes is usually easy to spot. Look for evidence of past rock falls, and check the floors of rock-cut spillways and unlined rock tunnels for excessive amounts of rock chips and pieces. Examine the walls for general deterioration. If there is evidence that portions of a concrete structure have moved due to thermal or chemically induced expansion or other causes, check rock abutments adjacent to the structure for spalling and possible crushing of rock at joints and fractures caused by pressure from concrete movement.

Seepage from rock cuts or from the floor of spillways cut in rock can create a number of potentially unsafe conditions. The inspector should evaluate the rate of seepage, correspondence of seepage rates to reservoir level, staining, and turbidity of seepage to fully understand the problem. Seepage can create excess hydrostatic pressure, weaken the overall strength of the rock walls, and produce increasingly large channels for water flow. Openings can enlarge sufficiently to cause slope movement or collapse. Stains from seepage water indicate solutioning of minerals which may reduce the shearing strength of the rock materials and cause rock consolidation. The inspector should take samples of the seepage so that the minerals can be identified. The inspector should also check the geologic data for evidence of deposits of limestone or other rock subject to solutioning that may underlie competent rock. Turbid flow indicates that internal erosion or piping is occurring. The inspector should check the construction records to see if rock walls and slopes were grouted to control seepage. If grouting was not done in the past, this procedure may control the seepage. If prior grouting proved inadequate to prevent or control seepage, a qualified dam safety professional should examine possible causes and sources of the seepage and evaluate corrective actions.

Deficient rock reinforcements, if used, can also result in slope stability problems in spillways cut in rock. Rock reinforcements such as bolts, anchors, dowels, and tendons may be installed in the rock tunnels and slopes of dams. Be sure to make a record of deficient rock reinforcements, including deterioration of the rock around fastening plates, loose bolts or plates, and corroded bolts, fastening plates, or wire grids (especially in the vicinity of seepage).

If the inspector observes rock deficiencies that may affect the safety of a dam, he/she should:

- Record the location and extent of the deficiencies, and photograph the affected areas.
- Determine the cause of the damage, if possible.
- Notify a qualified dam safety professional immediately if abutment movement or a rockfall in an unlined tunnel or spillway channel is suspected or observed.

6.5.7.3 Riprap

Riprap is deficient when it fails to protect the underlying earth from erosion. Many riprap deficiencies can be dealt with through routine maintenance, such as adding rock to areas where riprap has started to become displaced. More severe riprap deficiencies may threaten the safety of the dam. Undercutting by wave action, slides, and slope failure can lead to failure of a spillway channel, a plunge pool, or, if erosion continues unchecked, even the breaching of an embankment dam or dike.

Figure 6-38 Riprap degradation.

Riprap may suffer from displacement or rock degradation. These deficiencies may be related, with degradation often leading to displacement.

Displacement of riprap or the underlying slope material results from the removal of rocks from their as-placed position. Filter or bedding material may become exposed, or the riprap layer may become thinner, providing inadequate protection. Reasons riprap can become displaced include:

- Inadequate thickness of riprap layer
- Improper sizing or gradation of riprap relative to filter or bedding material (inner layer is washed through outer layer)
- Improper anchorage at base of protected slope
- Loss of foundation support
- Missing, inadequate, or improperly sized filter or bedding material
- Wrong shape (too slabby/flat, or too round: most problems are due to stones being too round and easily rolled by waves or flows)
- Rock weight insufficient (due to small size or low specific gravity) for anticipated wave action or flow velocity
- Too much variance in size and weight
- Average weight reduced by rock deterioration
- Nondurable rock
- Damage from ice movement in the reservoir
- Bedding not properly installed
- Poor grading of slope
- Improper foundation preparation
- Rock sizes segregated during placement
- Loose placement resulting in large voids

Rock degradation may be caused by high abrasion loss, structural weakness (cracks, fractures, etc.), high absorption rates (freeze-thaw damage from absorbed water), and impact damage from debris. Types of rock degradation include cracking, spalling, splitting or delaminating along bedding planes and joints, de-aggregating and disintegrating of poorly cemented sedimentary rock, and dissolving.

Riprap installations in areas exposed to numerous freeze-thaw cycles or high winds are most likely to experience serious problems. Be especially alert for riprap problems if the dams being inspected are exposed to these conditions.

Riprap exposed to high velocity flows or turbulence on a spillway channel, or in the lining of a plunge pool, is especially vulnerable. Rock may be displaced, or may degrade by becoming weathered and breaking down, thereby allowing damage to the underlying slope.

All riprap degrades over time, but wetting and drying, and freeze-thaw cycles accelerate degradation in spillway and outfall structures. Look for signs that the riprap is smaller near the waterline, that rocks are shattered, or that thinning of the riprap layer or gaps in the riprap have developed. The riprap layer may be so degraded and displaced that erosion of the underlying material has begun.

If riprap deficiencies that may affect the safety of the dam are observed, the inspector should:

- Record the location and approximate dimensions of riprap deficiencies.
- Look for signs of foundation and bedding deterioration.
- Photograph the area.
- Recommend temporary corrective actions.
- Consult a qualified dam safety professional to evaluate the need for major repair.

6.5.7.4 Gabions

Gabions may be used as lining and support in spillways, stilling basins, and other dam outfall structures. A gabion is a prefabricated rectangular wire cage or basket filled in place with rocks. Gabions are free-draining and capable of being stacked for erosion protection. The term "gabion wall" may be used to refer to stacked gabions, while "gabion mattress" refers to a layer of gabions used to protect a chute or basin floor.


Figure 6-39 Gabion baskets before installation.

Gabions are usually subject to various deficiencies that may cause deformation and possible toppling of gabion walls. These deficiencies include inadequate foundation support, foundation erosion, settlement of the rock within the basket, rock degradation, and failure of the wire baskets. Settlement and possible displacement of gabions can result from inadequate foundation support or from erosion of the subgrade. Foundation soils may be eroded when gabions are used because water flow can occur at the bottom of the basket. Proper foundation treatment is essential when gabions are installed in waterways. Rock within a gabion can shift and consolidate into a smaller space than when the basket was filled, creating unsupported space at the top of the basket. Rocks within gabions may spall, split, disintegrate, or dissolve. Flowing water can then wash pieces of rock through openings in the basket. The loss of rock mass makes the gabions susceptible to being lifted and moved by flows, and consolidation of rock within the basket creates empty, unsupported space at the top of the basket. The wires of the baskets may become corroded, broken or cut by vandals, or deformed by rapidly flowing


Figure 6-40 Gabion-lined emergency spillway.

water. Rocks may be washed out of a damaged basket, and the basket can be deformed by the weight of shifting rocks or other gabions, and fail.

Failure of gabion channel protection may result in exposure of slopes or channel floors to erosion, undercutting, and subsequent failure. When gabion structures consist of stacks or rows of baskets, the integrity of individual baskets is crucial to the integrity of the structure. Baskets are prone to deformation because basket wires can bend, corrode, and break, and stones can shift, deteriorate, or be dislodged.

Some settlement of a gabion installation is normal. Gabions are designed to be flexible and allow for some degree of settling. Minor deterioration in a gabion installation generally constitutes a long-term maintenance problem rather than a hazard to the dam. Hazardous gabion deficiencies are those that destabilize the installation, or cause it to fail entirely, usually because of deficiencies in a limited number of baskets.

The lower baskets in a vertical or battered gabion wall support the greatest weight, and are most likely to become deformed. Because of their position, failure of lower baskets carries great potential to destabilize a gabion installation. Defects such as broken, cut, or deformed wires and missing rock can lead quickly to failure of the individual gabion and subsequent failure of a wall. Look for damaged baskets or baskets crushed by overlying gabions, and for movement and undermining caused by waves or current.

If the inspector observes gabion deficiencies that may affect the safety of the dam, he/she should:

- Record the location and extent of defective areas, and describe the nature of the deficiency; i.e., basket wires broken, degree of deformation or settlement, approximate amount of missing rock, etc.
- If the underlying slope is exposed, record the extent of slope damage, using such measurements as the length, width, and height of the affected area.
- Photograph the damaged area.
- Recommend corrective action and timing.

6.5.8 Synthetic Materials

Synthetic materials are often used in spillways and outlet works for discharge (conduits or pipes), drainage and seepage control (geotextile separators, geomembrane liners), and for filter media. Synthetic materials are also commonly referred to as geosynthetic materials because they are often used to replace earth materials in construction. In general, synthetic materials are not visible for examination during inspection. The inspector will detect most deficiencies in synthetic materials by noting indirect signs, such as changes in drainage amounts, or foundation erosion.

Synthetic materials used at dams generally fall into in three broad categories: (1) geotextiles, (2) geomembrane linings, and (3) plastic piping and tubing (often referred to as geopipes).

A deficiency in a geotextile or geomembrane lining may severely affect the integrity of the incorporating structure. In the case of geotextiles within a dam, the deficiency could cause the dam to fail from internal erosion or piping. Deficiencies of geotextiles used for slope protection could result in a slope failure. The deficiency may affect a structure crucial to the safe operation of a dam, such as a spillway or plunge pool.

Table 6-9
Common Deficiencies in Geotextiles and Geomembranes

- Punctures and damage
  - Spreading equipment
  - Installation of anchorage fasteners
  - Construction or maintenance activities
  - Dropping riprap without cushioning
- Seams unbonded or poorly bonded
  - Seams opened under load
  - Poor bond between new and old fabric
- Sections incorrectly positioned or overlapped
- Displacement (usually slippage down slope)
- Soil piping through broken or open seams or punctures
- Clogging with soil particles (geotextiles only)
- Design problems
  - Lack of strength or durability for intended use
  - Incorrect match to soil base (improper filtering)
  - No anchorage provided
  - Inadequate transmission of water (Inadequate porosity)
- Defective materials
  - Lack of specified strength or durability
  - Holes or weak areas
- Deterioration
  - Aging
  - Temperature extremes (especially at or below the freezing point)
  - Exposure to ultraviolet light (sunlight)
  - Adverse chemical or biological conditions

Inspectors are usually most successful with detection of deficiencies in geotextiles and geomembrane linings in dams when they record the amount of seepage at drains and check the clarity of the water that is collected. If seepage has decreased and water pressure within the embankment has increased, as measured by a piezometer, geotextiles within the embankment may be clogged. Undrained seepage may be building hydrostatic pressure inside the embankment, weakening soil strength, or eroding the embankment. Turbid flow indicates piping and loss of material.

The following subchapters describe specific safety concerns for the various synthetic materials that may be used at dams and spillways.

6.5.8.1 Geotextiles

Geotextiles are water permeable, are generally made from polypropylene or polyester, and can be woven, nonwoven, or a combination of woven and nonwoven segments. Uses for geotextiles include separation between layers of materials, drainage, reinforcement, and filtration. In dams, geotextiles may have temporary or permanent construction uses. Geotextiles placed as embankment dam core and foundation filters would be extremely difficult to replace if problems develop, and such uses have generally not been embraced by the profession as accepted applications.

Geotextiles are sometimes used in lieu of granular filters beneath other erosion control materials such as riprap on the dam embankment or surfaces in spillways and plunge pools.

Geotextiles serve to control or prevent the movement of soil fines under riprap or similar materials used for slope protection and for lining spillways and plunge pools. Punctures and other deficiencies may result in loss of bedding material and erosion of foundation material beneath the geotextile, leading to sunken areas and voids under the riprap.


Figure 6-41 Articulating blocks are being placed over a geotextile filter on a dam embankment.

When a geotextile fails, the failure may jeopardize the structure which incorporates the geotextile. If seepage in a protected slope is restricted from entering a collector drain because of a clogged geotextile, excessive hydrostatic pressure could develop in the embankment or slope which could lead to slope failure. A ruptured geotextile could lead to piping of the embankment material because the filtering capacity is lost, at least locally.

Clogging of geotextiles under riprap may also cause a buildup of hydrostatic pressure at the toe, saturating the slope, and potentially resulting in a local failure that is seen as bulging at the slope toe until the geotextile breaks. After the geotextile breaks, a washed-out area will develop.

If deficiencies in geotextiles that could affect the safety of the dam are observed, the inspector should:

- Photograph and record the observations that indicate possible problems with the geotextiles.
- Determine the function of the geotextile, and the cause of the problem.
- Refer problems with geotextiles to a qualified dam safety professional.

6.5.8.2 Geomembranes

Geomembrane linings are impermeable, and are typically used as water barriers. Geomembrane linings may be composed of various materials, the most commonly used being PVC (polyvinyl chloride), CSPE-R (chlorosulfonated polyethylene-reinforced), HDPE (high density polyethylene), VLDPE (very low density polyethylene), and neoprene. Dams with seepage problems may deploy a geomembrane on the upstream face of the dam to control seepage. Geomembranes are not commonly used at dams or spillway structures.
A failed geomembrane reservoir liner can permit seepage through porous foundation

zones which might cause piping to develop.

For reservoirs sealed with a geomembrane liner, unaccountable losses from the reservoir may be the first clue that the liner is leaking. Seepage around the reservoir rim is another indicator. The inspector should examine the reservoir floor with the reservoir drawn down if possible. Examine the protective layer over the membrane liner for gaps, plant growth, animal burrows, damage from vandalism, and piercing of the liner.

Figure 6-42 A geomembrane liner being installed in a waste water reservoir.

If deficiencies in geomembrane linings that could affect the safety of the dam are observed, the inspector should:

- Photograph and record the observations that indicate possible problems with the geomembrane linings.
- Determine the cause of the problem.
- Refer indications of geomembrane lining failure to a qualified dam safety professional.

6.5.8.3 Geopipes

Plastic piping and tubing (geopipes) are often used in dam spillway and outlet works, although this practice is not recommended in Indiana. Furthermore, plastic pipes have not been proven to be safe in spillway applications. Most geopipes are made of PVC (polyvinyl chloride), ABS (acrylonitrile butadiene styrene), and PE (polyethylene).

Table 6-10
Types of Geopipe Deficiencies

Mechanical damage

- Cracks
- Breaks
- Split seams
- Disbonded fitting/joints
- Poorly welded joints
- Shear at wall-backfill interface
- Crushing by stones in backfill or vehicles driven on embankment, or other loads
- Burned or deformed when exposed in areas where surface vegetation is controlled by burning

Deterioration

- Exposure to ultraviolet light (sunlight)
- Chemical attack
- Stress-deformation (creep), buckling
- Localized sources of high heat, including burning

Plastic pipe is used for conveying water and other fluids, but the pipe must be protected from mechanical damage. Plastic piping and tubing usually are embedded in concrete or buried underground for protection.

Common uses for plastic piping and tubing include:

- Piezometer tubing used to measure water pressure in earth structures or foundations and abutments

- Tubing in stilling wells
- Electrical conduit
- Seepage collectors in drainage systems (PE)
- Outlet works conduits (PE and PVC)

Deficiencies of plastic pipes that affect the safety of the dam generally involve drainage systems. Malfunction of plastic pipes used as seepage collectors in drainage systems could result in excess or leaking drainage water building hydrostatic pressure inside the embankment, the dam, or in the foundation, causing a loss of strength, reduction of safety against slope failure or sliding, and possible failure at the downstream toe or slope. Seepage also may erode soil from within the dam or foundation into a broken or damaged collector system.

If plastic pipes are used in any application at a dam or reservoir, a detailed engineering analysis of the application must be performed and installation techniques must be carefully specified. Only “thick-walled” plastic pipe should be considered for use, and IDNR or a qualified dam safety professional should be consulted prior to its use. In general, the use of plastic pipe for spillway discharge conduits is not recommended.


Figure 6-43 Plastic pipe used as the principal spillway; the use of this type of pipe is not recommended

The inspector should check for safety deficiencies in plastic pipe used in drainage systems. Past inspection reports and other documentation may contain drainage measurements to compare with current observations. Signs of potentially hazardous conditions in plastic piping and tubing include leaking fittings and joints, visible impact damage, warp or creep, silted or obstructed flow area, plugged outlets obstructing free flow (lack of flow - operates only during wet weather), crushed pipe, burned surfaces, and turbidity or sediments in the discharge.

When inspecting unexposed pipe, reduced flow, turbid flow, or lack of flow are indicators of possible problems with the pipe. The following procedures can be used to help identify problems with unexposed or buried pipes:

- Pull a plug through the pipe to test for obstructions (if open at two ends)
- Inspect the pipe interior using a remotely operated video or television camera
- Use a motorized drain cleaning tool to clear possible obstructions
- For a pipe that should be watertight, pressurize the pipe with air or water, and check the pressure to detect leaks (not recommended unless very low pressures are used, since a sudden break or release could damage the embankment)

If a deficiency in plastic piping and tubing that may affect the safety of the dam is observed, the inspector should:

- Record the observations and procedures used to investigate changes in drainage patterns.
- Describe any findings about the causes of the deficiency, and possible corrective actions.
- If the apparent volume of leakage into the embankment is sizable, consult a qualified dam safety professional for further evaluation.

6.6 OBSTRUCTIONS


Figure 6-44 Trash in this spillway outlet channel obstructs the flow.

Obstructions can reduce the capacity or operation of spillways and outlets. Obstructions of surface features are usually easy to detect. However, obstructions within buried or submerged conduits and other structures may not be readily apparent. The spillway, the approach to the spillway, and the downstream exit channel could be obstructed by excessive growth of grass and weeds, thick brush, trees, debris, or landslide deposits. An obstructed spillway will have a substantially reduced discharge capacity. This reduced capacity can create serious problems, including embankment overtopping or complete dam failure.


Figure 6-45 A building constructed in the emergency spillway obstructs flow and poses a safety risk to the building.

Earthen emergency spillways are particularly prone to excessive vegetative growth. There should be no trees, shrubs, or brush in any emergency spillway. Man-made structures, unless considered in the original design for spillway adequacy, should not be built in emergency spillways. The inspector should always recommend the removal of trees, shrubs, and other obstructions in the emergency spillway. Figure 6-44 shows a spillway discharge channel with excessive trash. Figure 6-45 shows a building constructed in an emergency spillway.

Grass is usually not considered as an obstruction. But tall weeds and brush should be

Figure 6-46 Excessive vegetation obstructs this riser structure.

periodically cleared and trees removed as soon as they are noticed. Brush and debris can be entangled with trees to form an effective obstruction. When this happens, an even and smooth flow pattern cannot be maintained. Consequently, the effective width and capacity of the spillway could be reduced and the potential for erosion increased.

Any substantial amount of dirt deposited in the spillway channel from sloughing, a landslide above the channel, or sediment transport into the area must be immediately removed. Timely removal of large rocks is especially important. Presence of rocks in the channel can obstruct flow and encourage erosion. A sudden plunge of the spillway to the stilling basin also results in abrasion of the channel lining and damage to the stilling basin.

Walls of spillways are usually equipped with weep (or drain) holes. Occasionally, spillway chute slabs are also equipped with weep holes. If all holes are dry, it is probably because the soil behind the wall or below the slab is dry. If some holes are draining while others are dry, then the dry holes may be plugged by mud or mineral deposits. Probe the plugged hole to determine probable causes of the blockage. Plugged weep holes increase chances for failure of the retaining wall or chute slab. Try to clean out dirt or deposits and restore draining ability. If this does not work, rehabilitation work must be performed under the supervision of a qualified dam safety professional as soon as possible.

Figure 6-47 Inappropriate trash rack over end of a culvert spillway.

Many dams in Indiana have pipe and riser spillways. Pipe spillway inlets that become plugged with debris or trash reduce spillway capacity. As a result, the potential for overtopping the dam is greatly increased, particularly if there is only one spillway. If the dam has an emergency spillway channel, a plugged principal spillway will cause more frequent and greater than normal flow in the emergency spillway. Since emergency spillways are generally designed for infrequent flows of short duration, serious damage may result. For these reasons trash collectors or racks must be installed at the inlets to pipe spillways and lake drains and trash must be removed whenever it restricts the inlet capacity.

Figure 6-48 Poorly constructed trash rack has openings that are too large at the riser crest.

A well-designed trash rack will stop large debris that could plug the discharge pipe but allow unrestricted passage of water and smaller debris. Some of the most effective racks allow flow to pass beneath the trash into the riser inlet as the pool level rises. Racks usually become plugged because the openings are too small, or the head loss at the rack causes material and sediment to settle out and accumulate. Small openings will stop small debris such as twigs and leaves, which in turn cause a progression of larger items to build up, eventually completely blocking the inlet. Trash rack openings should be at least 6 inches across regardless of the pipe size. The larger the principal spillway conduit, the larger the trash rack opening should be. The largest possible openings should be used, up to a maximum size of about 2 feet.

Figure 6-49 Riser lacking a trash rack can clog and cause dam overtopping.

The trash rack should be properly attached to the riser inlet, and strong enough to withstand the hammering forces of debris being carried by high velocity flow, a heavy load of debris, and ice forces. If the riser is readily accessible, vandals could throw riprap stone into it. To prevent such vandalism, the size of the trash rack openings should not be decreased, but rock that is larger than the openings or too large to handle should be used in the vicinity of the riser.

The lack of a trash rack is unacceptable, and creates the potential for an extremely hazardous condition. Trash racks constructed from very thin wire, such as “chicken wire,” that can be easily damaged or destroyed is also unacceptable. Trash racks that are “flat” and cover only the opening of a riser (i.e. constructed similar to a grate over a drop inlet on streets) are also safety concerns because of the potential for clogging. In either case, the inspector should recommend the installation of a proper trash rack.

Maintenance should include periodically checking the trash rack for rusted and broken sections, and repairing it as needed. The trash rack should be checked frequently during and after storm events, to ensure it is functioning properly, and to remove accumulated debris.

Vegetated earth spillways are commonly used as an economical means to provide emergency spillway capacity. Normal flows are carried by the principal spillway, and infrequent large flood flows pass primarily through the emergency spillway. For dams with pipe-conduit spillways, an emergency spillway is almost always required as a back-up in case the pipe becomes plugged. These spillways are often neglected because the owner rarely sees them flow.

Beavers may present problems at dams where they may live since they have a natural tendency to block off spillways with brush and sticks. Beavers are attracted to the sound of running water and tend to build dams where they hear this sound. Beavers should be eliminated or relocated if they become a problem, or a control device should be constructed at the spillway to prevent their approach.

Figure 6-50 Beavers have blocked this spillway.

Figure 6-51 Trees growing in emergency spillway.

Periodic mowing in the grass-lined spillways is required to prevent trees, brush, and weeds from becoming established, and to encourage the growth of grass. Poor vegetal cover will usually result in extensive, rapid erosion when the spillway flows, and will require more costly repairs. Trees and brush may reduce the discharge capacity of the spillway. The inspector should evaluate the degree of vegetative growth in the earthen spillways. Tree and shrub removal should always be recommended if these plants are present.

Erosion can be expected in the spillway channel during high flows, and can also occur as a result of rainfall and local runoff. The latter is more of a problem in large spillways, creating gullies where low flows tend to concentrate, and may require special treatment, such as terraces or pilot channels. Erosion of the side slopes deposits material in the spillway channel, especially where the side slopes meet the channel bottom. In small spillways, this can significantly reduce the spillway capacity. This condition often occurs immediately after construction, before vegetation becomes established. In these cases, it may be necessary to reshape the channel to provide the necessary capacity.

Emergency spillways often are used for purposes other than passage of flood flows. Among these uses are reservoir access, parking lots, boat ramps, boat storage, pasture and cropland. Permanent structures (buildings, boat docks, fences, etc.) should not be constructed in these spillways.

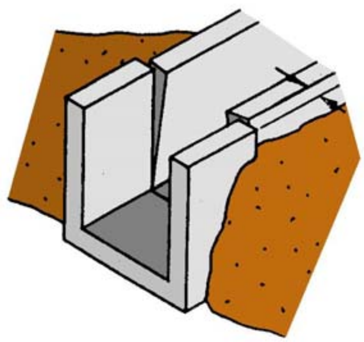
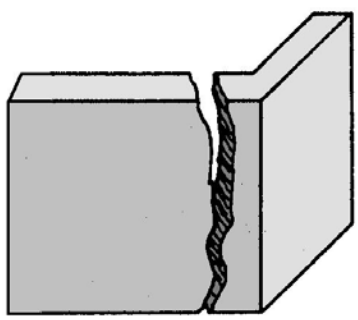
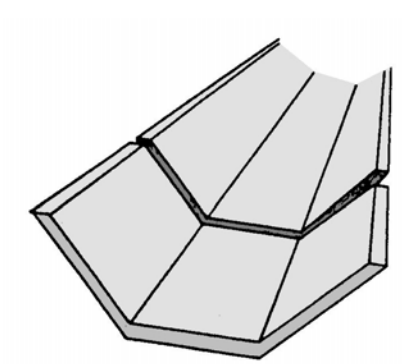
During inspection of spillways and outlets for obstructions, the inspector should:

- Describe the location, type and extent of any obstruction that may be present.
- Photograph the obstruction.
- Recommend corrective action and timing.

6.7 SPILLWAY AND OUTLET INSPECTION SKETCHES

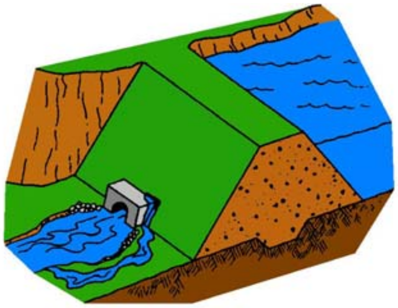
The following pages contain sketches of conditions that may be found on the spillway or outlet of the dam during an inspection. While most of the conditions on the following tables can be corrected by routine and periodic maintenance conducted by the owner, some of the conditions noted are of a nature that threaten the safety and integrity of the dam and require the attention of a qualified dam safety professional (if immediate emergency action is not required). Depending on the severity of the condition, the dam owner may need to take immediate action to prevent the condition from worsening, including contacting repair contractors, notifying local emergency authorities, and notifying downstream residents or occupants. A qualified dam safety professional is a person with specific expertise in the field of concern. For example, an engineer or geologist with geotechnical or geological experience may need to be consulted if a slope stability or soil issue exists. Or, an engineer with hydrologic and hydraulic experience may need to be consulted to determine spillway capacity.

Information on materials used in spillway outlet pipes and valves is included at the end of the sketches.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
WALL DISPLACEMENT 	**Probable Cause**: Poor workmanship; uneven settlement of foundation; excessive earth and water pressure; insufficient steel bar reinforcement of concrete. **Harm**: Minor displacement will create eddies and turbulence in the flow, causing erosion of the soil behind the wall. Major displacement will cause severe cracks and eventual failure of the structure.	**Potential Action**: Reconstruction or replacement should be done according to sound engineering practices. Foundation should be carefully prepared. Adequate weep holes should be installed to relieve water pressure behind wall. Use sufficient reinforcement in the concrete. Anchor walls to prevent further displacement. Install struts between spillway walls is required. Clean out and backflush drains to assure proper operations. Consult an engineer before actions are taken. *Qualified Dam Safety Professional Required*
LARGE CRACKS 	**Probable Cause**: Construction defect; local concentrated stress; local material deterioration; foundation failure, excessive backfill pressure. **Harm**: Disturbance in flow patterns; erosion of foundation and backfill; eventual collapse of structure.	**Potential Action:** Large cracks without large displacement should be repaired by patching. Surrounding areas should be cleaned or cut out before patching material is applied. Installation of weep holes or other actions may be needed. Replacement may be required in some cases.
OPEN OR DISPLACED JOINTS 	**Probable Cause**: Excessive and uneven settlement of foundation; sliding of concrete slab; construction joint too wide and left unsealed. Sealant deteriorated and washed away. **Harm**: Erosion of foundation material may weaken support and cause further cracks; pressure induced by water flowing over displaced joints may wash away wall or slab, or cause extensive undermining.	**Potential Action:** Construction joint should not be wider than 0.5 inches. All joints should be sealed with asphalt or other flexible materials. Water stops should be used where feasible. Clean the joint, replace eroded materials, and seal the joint. Foundation should be properly drained and prepared. Underside of chute slabs should have ribs of sufficient depth to prevent sliding. Avoid steep chute slope. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

SEEPAGE WATER EXITING FROM A POINT ADJACENT TO THE OUTLET



Probable Cause:

1. A break in the outlet pipe.

2. A path for flow from the reservoir has developed along the outside of the outlet pipe.

Harm:

Continued flows can lead to rapid erosion of embankment materials and failure of the dam.

Potential Action:

1. Thoroughly investigate the area by probing and/or shoveling to see if the cause can be determined.

2. Determine if leakage water is carrying soil particles.

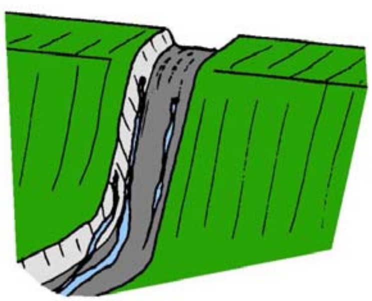
3. Determine quantity of flow.

4. If flow increases or is carrying embankment materials, reservoir level should be lowered until leakage stops.

5. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

LEAKAGE IN OR AROUND SPILLWAY



Probable Cause:

1. Cracks and joints in geologic formation at spillway are permitting seepage.

2. Gravel or sand layers at spillway are permitting seepage through embankment.

Harm:

1. Could lead to excessive loss of stored water.

2. Could lead to a progressive failure if velocities are high enough to cause erosion of natural materials.

Potential Action:

1. Examine exit area to see if type of material can explain leakage.

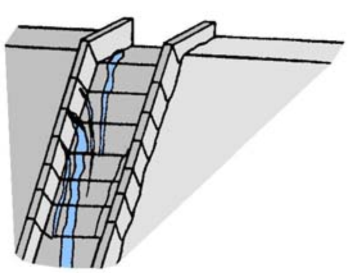
2. Measure flow quantity and check for erosion of natural materials.

3. If flow rate or amount of eroded materials increases rapidly, reservoir level should be lowered until flow stabilizes or stops.

4. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

SEEPAGE FROM A CONSTRUCTION JOINT OR CRACK IN CONCRETE STRUCTURE



Probable Cause:

1. Water from reservoir is collecting behind or under structure because of insufficient drainage or clogged weep holes.

2. Lack of cutoff wall.

Harm:

1. Can cause walls to tip in and over. Flows through concrete can lead to rapid deterioration from weathering.

2. If the spillway is located within the embankment, rapid erosion can lead to failure of the dam.

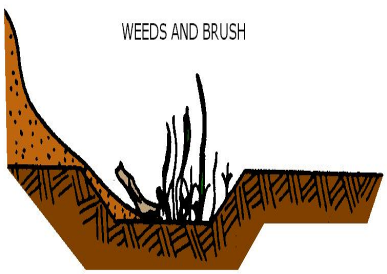
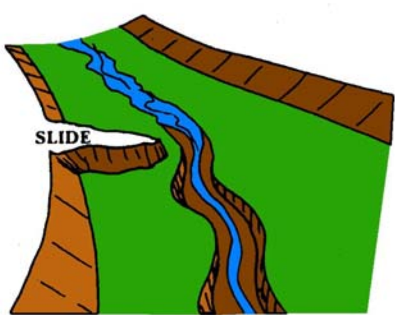
Potential Action:

1. Check area behind wall for puddling of surface water.

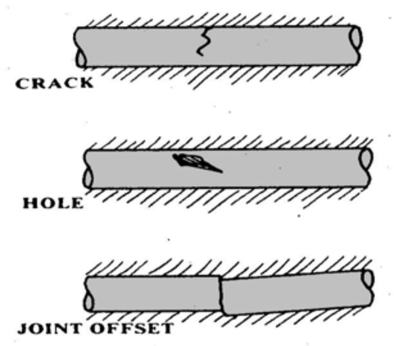
2. Check and clean as required: drain outfalls, flush lines, and weep holes.

3. If condition persists, a qualified engineer should inspect the condition and recommend further actions to be taken.

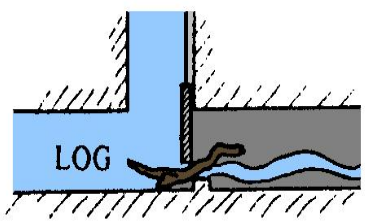
Qualified Dam Safety Professional Required

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
DEBRIS OR OTHER OBSTRUCTIONS 	**Probable Cause**: Accumulation of slide materials, dead trees, excessive vegetative growth, etc., in spillway channel. **Harm**: Reduced discharge capacity; overflow of spillway; overtopping of dam. Prolonged overtopping can cause failure of the dam.	**Potential Action:** Clean out debris periodically; control vegetative growth in spillway channel. Install log boom in front of spillway entrance to intercept debris.
EXCESSIVE EROSION IN EARTH-SLIDE CAUSES CONCENTRATED FLOWS 	**Probable Cause**: 1. Discharge velocity too high; bottom and slope material loose or deteriorated; channel and bank slopes too steep; bare soil unprotected; poor construction; protective surface failed. 2. Engaged too frequently. **Harm**: Disturbed flow pattern; Joss of material, increased sediment load downstream; collapse of banks; failure of spillway; can lead to rapid evacuation of the reservoir through the severely eroded spillway.	**Potential Action:** Minimize flow velocity by proper design. Use sound material. Keep channel and bank slopes mild. Encourage growth of grass on soil surface. Construct smooth and well compacted surfaces. Protect surface with riprap, asphalt, or concrete. Repair eroded portion using sound construction practices.
END OF SPILLWAY CHUTE UNDERCUT 	**Probable Cause**: Poor configuration of stilling basin area. Highly erodible materials. Absence of cutoff wall at end of chute. **Harm**: Structural damage to spillway structure; collapse of slab and wall; leads to costly repair. Higher velocity flows can cause erosion of drain, then embankment materials.	**Potential Action:** Dewater affected area; clean out eroded area and properly backfill. Improve stream channel below chute; provide properly sized riprap in stilling basin area. Install cutoff wall.

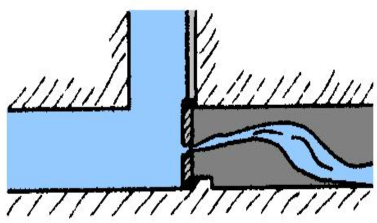
PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
OUTLET PIPE DAMAGE	**Probable Cause**: Crack: Settlement; impact, improper design or placement. Hole: Rust (steel pipe) Erosion (concrete pipe) Cavitation Joint offset: Settlement or poor construction practice. **Harm**: Provides passageway for water to exit or enter pipe.	**For all conditions**: Check for evidence of water either entering or exiting pipe at crack/ hole/etc. Tap pipe in vicinity of damaged area, listening for hollow sound which indicates a void has formed along the outside of the conduit. If a progressive failure is suspected, request qualified professional assistance.



PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
DEBRIS STUCK UNDER GATE	**Probable Cause**: Trash rack missing or damaged. **Harm**: Gate will not close. Gate or stem may be damaged in effort to close gate.	**Potential Action:** Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trash rack.

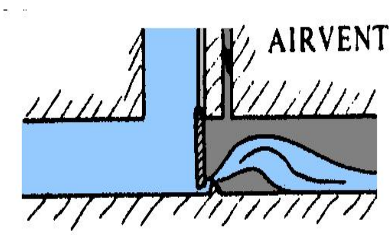


PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
CRACKED GATE LEAF	**Probable Cause**: Ice action, rust, impact, vibration, or stress resulting from forcing gate closed when it is jammed. **Harm**: Gate-leaf may fail completely, evacuating reservoir.	**Potential Action:** Use valve only in fully open or closed position. Minimize use of valve until leaf can be repaired or replace.



PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

DAMAGED GATE LEAF OR GUIDE



Probable Cause:

Rust, erosion, cavitation, vibration, or wear.

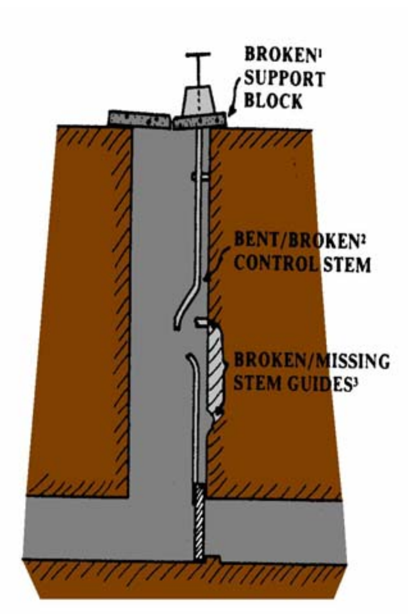
Harm:

Leakage and loss of support for gate leaf. Gate may bind in guides and become inoperable.

Potential Action:

Minimize use of valve until guides/ seats can be repaired. If cavitation is the cause, check to see if air vent pipe exists, and is unobstructed.

CONTROL WORKS



1. BROKEN SUPPORT BLOCK:

Probable Cause:

Concrete deterioration. Excessive force exerted on control stem by attempting to open gate when it was jammed.

Harm:

Causes control support block to tilt; control stem may bind. Control headworks may settle. Gate may not open all the way. Support block may fail completely, leaving outlet inoperable.

2. BENT/BROKEN CONTROL STEM:

Probable Cause:

Rust. Excess force used to open or close gate. Inadequate or broken stem guides.

Harm:

Outlet is inoperable.

3. BROKEN/MISSING STEM GUIDES:

Probable Cause:

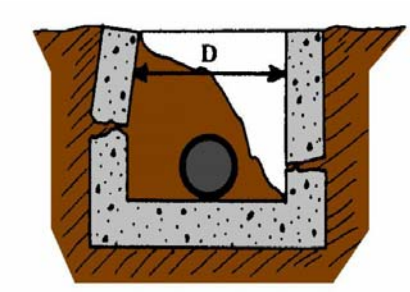
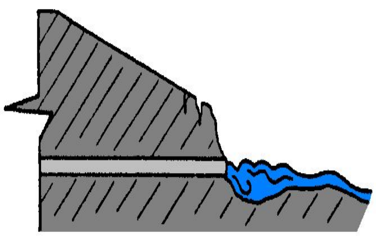
Rust. Inadequate lubrication. Excess force used to open or close gate when it was jammed.

Harm:

Loss of support for control stem. Stem may buckle and break under even normal use, (as in this example).

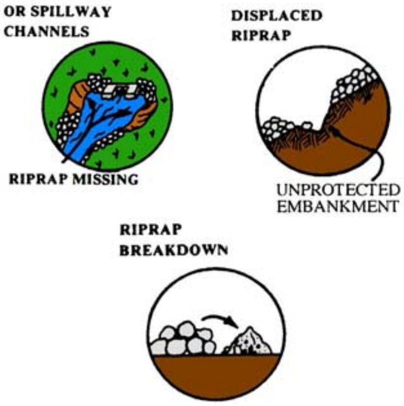
Potential Action:

Any of these conditions can mean the control is either inoperable or at best partially operable. Use of the system should be minimized or discontinued. If the outlet system has a second control valve, consider using it to regulate releases until repairs can be made. Engineering assistance is recommended.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
FAILURE OF CONCRETE OUTFALL STRUCTURE 	**Probable Cause**: Excessive side pressures on non-reinforced concrete structure. Poor concrete quality. **Harm**: Loss of outfall structure exposes embankment to erosion by outlet releases.	**Potential Action:** Check for progressive failure by monitoring typical dimension, such as "D" shown in figure. Repair by patching cracks and providing drainage around concrete structure. Total replacement of outfall structure may be required.
OUTLET RELEASES ERODING TOE OF DAM 	**Probable Cause**: Outlet pipe too short. Lack of energy-dissipating pool or structure at downstream end of conduit. **Harm**: Erosion of toe over-steepens downstream slope, causing progressive sloughing.	**Potential Action:** Extend pipe beyond toe (use a pipe of same size and material, and form watertight connection to existing conduit). Protect embankment with riprap over suitable bedding.

PROBLEMS | **CAUSES & HARM DONE** | **ACTION REQUIRED**

Breakdown or loss of riprap



Probable Cause:

Slope too steep; material poorly graded; failure of sub-grade; flow velocity too high; improper placement of material; bedding material or foundation washed away.

Harm:

Erosion of channel bottom and banks; failure of spillway.

Potential Action:

Design a stable slope for channel bottom and banks. Riprap material should be well graded (the material should contain small, medium, and large particles). Sub-grade should be properly prepared before placement of riprap. Install filter fabric if necessary. Control flow velocity in the spillway by proper design. Riprap should be placed according to specification. Services of an engineer are recommended.

Qualified Dam Safety Professional Required

Material deterioration-spalling and disintegration of riprap, concrete, etc.

Probable Cause:

Use of unsound or defective materials; structure subjected to freeze-thaw cycles; improper maintenance practices; harmful chemicals.

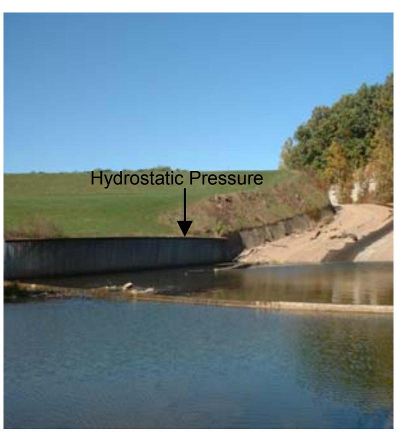
Harm:

Structure life will be shortened; premature failure.

Potential Action:

Avoid using shale or sandstone for riprap. Add air-entraining agent when mixing concrete. Use only clean good quality aggregates in the concrete. Steel bars should have at least 1 inch of concrete cover. Concrete should be kept wet and protected from freezing during curing. Timber should be treated before use.

Poor surface drainage



Probable Cause:

No weep holes; no drainage facility; plugged drains.

Harm:

Wet foundation has lower supporting capacity; uplift pressure due to accumulated seepage water may cause damage to spillway chute; accumulation of water may also increase total pressure on spillway walls and cause damage.

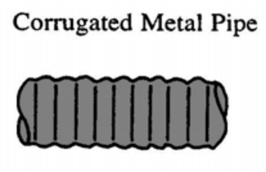
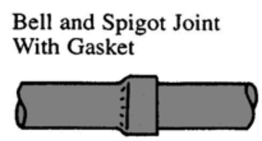
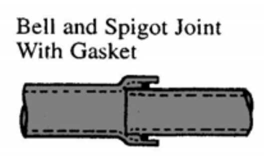
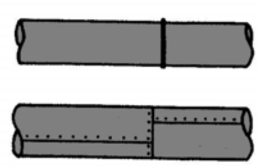
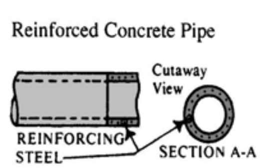
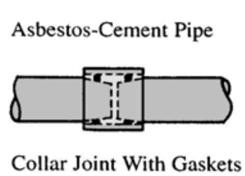
Potential Action:

Install weep holes on spillway walls. Inner end of hole should be surrounded and packed with graded filtering material. Install drain system under spillway near downstream end. Clean out existing weep holes. Back flush and rehabilitate drain system under the supervision of an engineer.

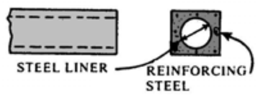
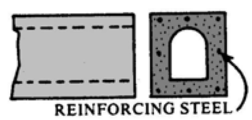
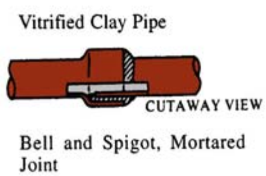
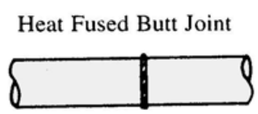
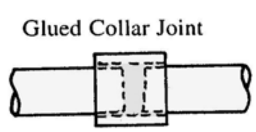
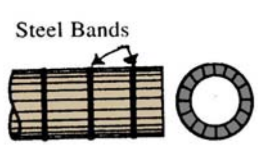
Qualified Dam Safety Professional Required

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
Concrete erosion, abrasion, and fracturing 	**Probable Cause**: 1. Flow velocity too high (usually occurs at lower end of chute in relatively high dams); rolling of gravel and rocks down the chute; cavity behind or below concrete slab. 2. Absence of cutoff wall. **Harm:** Pock marks and spalling of concrete surface may progressively become worse; small hole may cause undermining of foundation, leading to failure of structure.	**Potential Action:** Remove rocks and gravels from spillway chute before flood season. Raise water level in stilling basin. Use good quality concrete. Make sure concrete surface is smooth. *Qualified Dam Safety Professional Required*

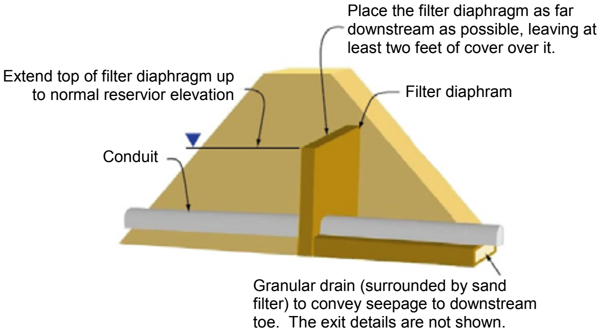
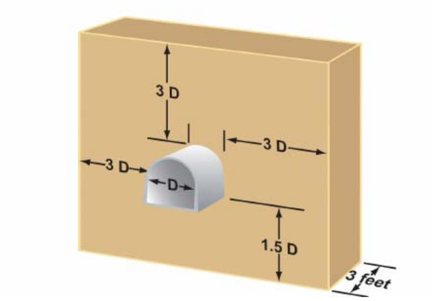
MATERIALS USED IN OUTLET PIPES

<u>TYPE</u> **[METAL PIPES]**	**DRAWING OR DESCRIPTION**	**ADVANTAGES**	**DISADVANTAGES**
1. CMP		Low cost. Light weight. Flexibility.	Not watertight; can't be used as pressurized pipe. Requires tar protection to inhibit rusting. Subject to structural collapse under high loading. Roughness reduces capacity. Not recommended.
2. CAST IRON		Durable. History of satisfactory service commonly exceeds 100 years. Oxides of corrosion adhere and help protect the pipe from further attack. High strength.	Brittle and difficult to weld; cracks if subjected to severe impact or ice action. Tubercu-lation (formation of rust mod-ules) decreases pipe inside diameter and increases rough-ness; cement lining usually desirable.
3. DUCTILE IRON		High strength with some flex-ibility; not brittle like cast iron. (Other advantages similar to cast iron.)	Tuberculation. (See Cast Iron.)
4. STEEL		High strength and flexibility without cracking. Easily welded for water-tight connection. Forms good liner for concrete encased pipe.	Failure by rusting or chemical attack; oxides flake-off, expos-ing pipe to further attack. Surface protection required. Coating should be applied.
[CONCRETE PIPES]			
1. RCP		High strength. Not subject to corrosion. Rubber gasket joints form watertight connection.	Brittle; can chip or crack if subjected to impact or differ-ential settlement. Heavy; dif-ficult to handle. Subject to erosion by sediment washed through pipe.
2. ACP		Will not corrode; contains no metal or organic material. Light weight; easy to install.	Brittle; can be broken by impact or differential settlement.

MATERIALS USED IN OUTLET PIPES

<u>TYPE</u> **[CONCRETE PIPES]**	**DRAWING OR DESCRIPTION**	**ADVANTAGES**	**DISADVANTAGES**
3. CONCRETE ENCASED PIPE		Adds strength to the steel conduit, by surrounding it with reinforced concrete. If the liner rusts out, outlet can usually be repaired by relining.	Added cost.
4. CAST-IN-PLACE CONCRETE CONDUIT		High strength. Any size or shape can be constructed.	Special forming required; added cost.
[MISCELLANEOUS MATERIALS]			
1. VCP		Will not corrode. Smooth interior; less resistance to flow.	Brittle; pipe and joints easily damaged by impact or differential settlement. Not normally used as pressure pipe; joints may leak. Not recommended for any use.
2. POLYETHYLENE		Flexible and very tough; will not develop stress cracks. Lightweight and will not corrode. Very smooth; little resistance to flow. Watertight.	Limited in-place testing. May collapse or creep under high loading; concrete encasement may be required.
3. PVC		Lightweight and inexpensive. Easy assembly; no special tools. Smooth and will not corrode.	Limited in-place testing. May "sunburn" and become brittle if exposed to sunlight for extended periods of time. Recommended for underdrains only; do not use as spillway or outlet conduit.
4. WOOD STAVE		Will not rust. Smooth and not damaged by freezing. Lightweight.	Relatively short life unless kept saturated. High cost of maintenance. Seldom used in current design. High leakage; low strength. Not recommended for any use.

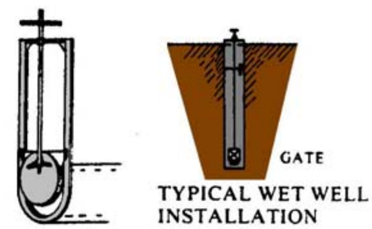
SAND FILTER DIAPHRAGM

TYPE	DRAWING OR DESCRIPTION	USES AND DISCUSSION
SAND FILTER DIAPHRAGM (TYPICAL CONFIGURATION)		The preferred method of seepage control. Prevent seepage water from removing soil from around coduit. Commonly connected to a horizontal granular layer or pipe drain to convey seepage from the diaphragm away from the embankment.
SAND FILTER DIAPHRAGM (TYPICAL DIMENSIONS)		
SAND FILTER DIAPHRAGM (PHOTOGRAPH)		

OUTLET VALVES

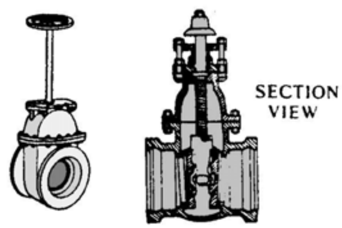
<u>TYPE</u> **DRAWING OR DESCRIPTION** **USES AND DISCUSSION**

SLIDE GATE OR SLUICE GATE



The most common type of valve. Used as regulating or guard valve at upstream end of outlet pipe, or in wet well. Mechanically simple and available in a variety of sizes and shapes. Suitable for dams of low to moderate height. If used to regulate flow, an air vent is recommended just downstream of the valve.

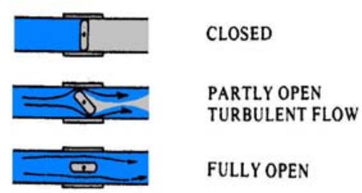
GATE VALVE



Typically used as a regulating valve or guard valve at the upstream end of the conduit or in an outlet well. Since the valve is watertight, the outlet well remains dry. The gate leaf is wedge-shaped and seals into a tapered seat.

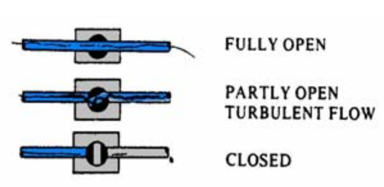
If a gate valve is used for regulation, an air vent is recommended just downstream of the valve.

BUTTERFLY VALVE



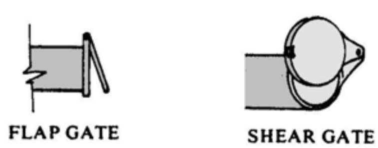
Performs best as an upstream guard gate. If used for regulation, certain valve openings cause turbulence and cavitation. Air vent required downstream of valve, if used for regulation.

BALL VALVE, PLUG VALVE, OR CONE VALVE



Used in low head situations or as a guard valve. Intermediate valve settings may result in turbulence and cavitation (air vent recommended).

FLAP GATE, SHEAR GATE



Used as guard gate at end of outlet conduit. Normally in the fully open position. Valve is closed only to dewater the outlet conduit for maintenance, inspection, or in an emergency. Prevents backwater from flowing into the pipe.

CHAPTER 7.0

INSPECTION OF CONCRETE DAMS

7.0 INSPECTION OF CONCRETE DAMS

7.1 INTRODUCTION

The purpose of safety inspections is to identify deficiencies that potentially affect the safety of the dam. An inspector should develop a methodical procedure for inspecting a concrete dam to ensure that all features and areas are examined and to minimize the amount of time spent in the field. Concrete dams are potentially very stable when designed and constructed properly, and are not usually prone to overtopping failures, erosion, slides, burrowing animals, and piping, all of which are common safety problems at embankment dams. Concrete dams are prone to undermining at the toe due to excessive seepage or soil erosion, and are subject to sudden failure of a segment or piece of the structure.

Figure 7-1 A concrete gravity dam in Indiana.

Figure 7-2 Most concrete dams in Indiana are in-channel structures that are difficult to inspect.

Concrete dams require special visual inspection techniques due to their steep faces. Special safety harnesses, boatswain chairs, boats, video equipment, and scuba divers may be required to complete the inspections.

Most concrete dams in Indiana are in-channel structures that are difficult to inspect because they are continuously inundated with overflow, and typically have a lot of debris on the structure (see Figures 7-2 and 7-3). Sometimes these concrete structures are contained in or along earth embankments.

Low head dams constructed across streams and rivers present a safety hazard in the area immediately downstream of the dam. The whirlpools, hydraulic jumps, and eddies created from the discharging water are extremely dangerous to boaters and swimmers, and there have been many

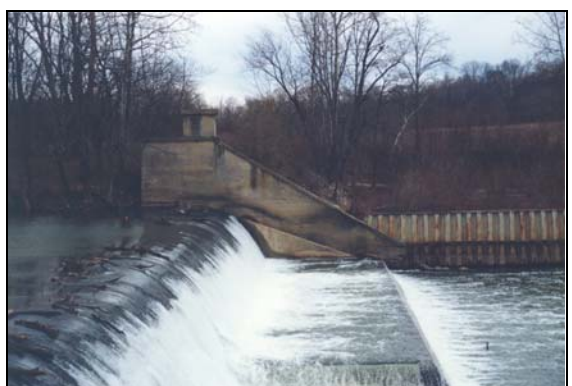


Figure 7-3 Low head, in-channel concrete dams are very dangerous due to the whirlpools, hydraulic jumps, and eddies on the discharge side.

drowning accidents that have occurred in such areas. It can be very difficult or impossible for swimmers and boats to escape from this area, especially during periods of increased flow following precipitation events. For this reason, these dams are often referred to as “drowning machines.”

Concrete dams include gravity, arch, roller-compacted, and buttress types. Concrete gravity dams depend on their mass for stability and are generally adapted to sites where there is a reasonably sound rock foundation, or occasionally a dense alluvial foundation. Concrete arch dams are adaptable to sites where the ratio of width between abutments to height of dam is not great and where the foundation at the abutments is solid rock capable of resisting arch thrust. Buttress dams utilize a sloping membrane, generally of concrete, to transmit hydrostatic forces to a series of structural buttresses placed at right angles to the axis of the dam. The most common buttress dams are the flat-slab and multiple arch. Buttress dams are best suited to wide valleys with gradually sloping abutments; they can be founded on rock or sound alluvium. Roller compacted concrete (RCC) dams utilize a relatively new method of construction that combines the safety and benefits of concrete dams with the rapid continuous-placement methods normally associated with earth embankment dams. RCC dams are constructed with zero-slump concrete using vibratory rollers.

The remainder of this chapter describes visual inspection techniques for concrete dams and the concrete portion of dams. Spillways and outfalls on concrete dams (and embankment dams) were described earlier. The information on concrete spillways and outfalls also applies to concrete dams, and should be used as necessary during visual inspections.

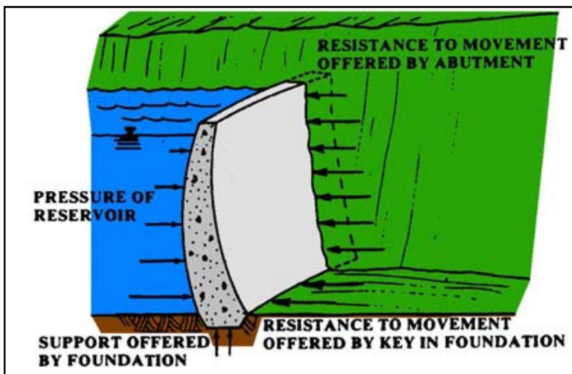


Figure 7-4 Typical forces acting on a concrete arch dam.

7.2 ITEMS OF CONCERN

From a safety standpoint, the principal advantage of concrete dams is that they will not erode during overtopping (although the abutments or foundation could). Embankment slides and piping failures, typical of earth dams, are also prevented by the concrete structure.

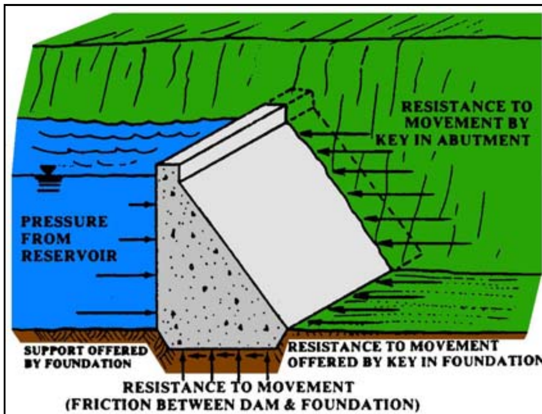


Figure 7-5 Typical forces acting on a concrete gravity dam.

It is important that concrete dam owners are aware of the principal modes of failure and that they are able to discern between conditions which threaten the safety of the dam and those which merely indicate a need for maintenance. Concrete dam design requirements are much different from embankment dams, and generally require more specific expertise to design, construct, inspect, and maintain.

Concrete dams fail for reasons different than embankment dams. Potential problems that may occur are discussed below. If any of these conditions are discovered during a visual inspection, the owner should obtain qualified professional assistance immediately.

The principal items that are potentially hazardous at concrete dams are structural cracking, foundation or abutment weakness, and deterioration. The water in the reservoir exerts substantial hydrostatic forces on the concrete structure, and the concrete structure exerts very large forces on the foundations and abutments.

Damage or failure of a structural component may occur because of an outside condition such as an embankment slide, or meteorologic or seismic event, which has subjected a structure to forces in excess of design. Damage to a structure may also be due to the absence of a formal design, a poor design, or poor construction. Structural problems usually contribute to the dam's susceptibility to failure during normal service.

7.3 CRACKS AND STRUCTURAL PROBLEMS

A crack is a separation of portions of a concrete structure into one or more major parts, and is usually the first sign of concrete distress. Cracks provide openings in the concrete that permit further deterioration of the concrete. A concrete dam and its appurtenances must withstand considerable hydrostatic pressure from the reservoir and groundwater. Hydrostatic pressure acting along cracks through the concrete structure may exert dangerous uplift forces on the structure, possibly leading to lateral propagation of the cracks and uplifting, settlement, sliding of a portion of the structure, and seepage. The inspector should examine all visible concrete surfaces for any signs of cracking, structure movement, and water seepage through the dam.

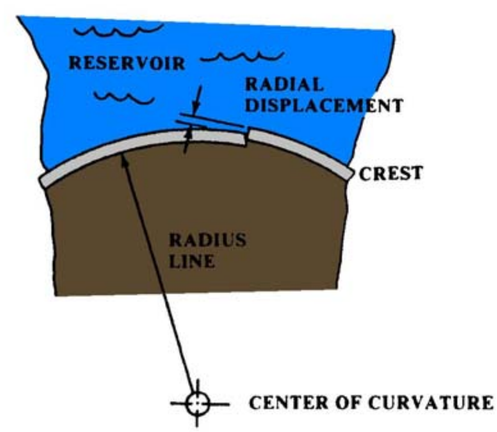


Figure 7-6 Serious cracking in an arch dam, with radial displacement.

Serious threats to concrete dams often involve cracks in the dam, abutments, or foundation. Cracks may develop slowly at first, making it difficult to determine if they are widening or otherwise changing over time.

Even if a crack itself does not present a serious threat, the mechanism causing the

Table 7-1
ACI Standardized Terminology for Individual Concrete Cracks

Direction
Longitudinal
Transverse
Vertical
Diagonal
Random

Width
Fine: less than 0.5 mm
Medium: between 0.5 and 2 mm
Wide: over 2 mm

Depth
Actual depth

Consistent with terminology used for cracking in embankment dams, some nomenclature for cracks in concrete dams differentiates cracks, on and parallel to the crest of a structure - termed longitudinal - from cracks on faces of the structure, which are designated as horizontal. ACI uses the term longitudinal to describe cracks in either location that are parallel to the crest. ACI 201.1, *Guide to Making a Condition Survey of Concrete in Service*, is a useful document that should be used if the inspector needs more information.

crack may threaten the structure. Cracking in concrete may be a visible indication of stress or movement, which the concrete cannot accommodate. The underlying cause of cracking may pose an immediate threat to the dam; therefore, the inspector should make every effort to determine the cause. The inspector must have a thorough understanding of the soil conditions in the foundation and the abutments when determining the cause of cracking.

There are two general categories of cracking typically found on concrete structures: (1) **individual cracks**, and (2) **pervasive cracks**. A concrete structure may have one or a limited number of individual cracks that can be measured and documented during the course of a visual inspection. Or, numerous cracks may be visible within areas of a concrete surface, or the cracking may affect the entire surface. This condition is known as pervasive cracking. Pervasive cracking usually is a sign of concrete deterioration.

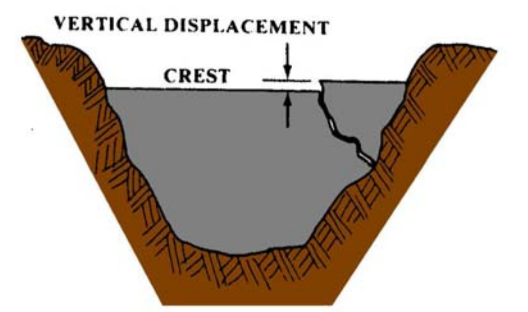


Figure 7-7 Foundation settlement or piping may lead to structural cracking with vertical displacement.

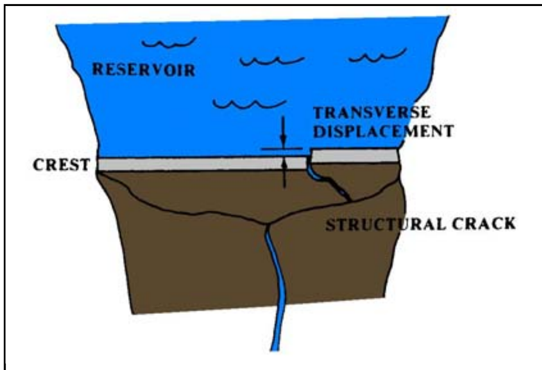


Figure 7-8 Structural crack with transverse displacement and significant seepage.

The inspector should carefully examine all visible concrete surfaces for the presence of cracks. If water is seeping from cracks on the downstream face, an underwater inspection of the upstream face may be required, depending on the severity of the problem and the amount of water seeping from the cracks.

The American Concrete Institute (ACI) has developed standardized terms to describe the appearance of individual cracks. These terms are listed on Table 7-1; it is recommended that the inspector use this terminology to describe cracks in concrete dams and structures. After the inspector has classified the cracks as either individual or pervasive crack, he/she should then further describe the cracks using the ACI terminology on Table 7-1 for individual cracks, or the terminology described below for pervasive cracks.

ACI uses three general classifications to describe extensive or pervasive cracking of concrete surfaces based on the shape of the cracks: (1) pattern cracking, (2) D-cracking, and (3) checking. Therefore, pervasive cracking should be further classified based on these shape descriptions (see Chapter 6 for sketches). When the concrete exhibits extensive pervasive cracking, the focus of the visual inspection should be the nature and extent of cracking rather than the dimensions of individual cracks.

Deterioration of the mass concrete in a dam can be caused by unusual or extreme stresses within the structure. Once structural movement and cracking have occurred, the damage may continue from freeze-thaw action, chemical action, or from normal weathering of the concrete. The inspector should examine cracks closely for signs of weathering and movement.

Structural cracks are caused by overstressing of portions of the dam, and are usually caused by inadequate design, poor construction techniques, or faulty materials. Structural cracks are often irregular, meaning they run at an angle to the major axes of the dam and may exhibit abrupt changes in direction. These cracks may also have noticeable radial, transverse, or vertical displacement. Overstressing in a concrete dam normally creates areas of distress and cracking that usually can be identified visually during a visual inspection. Cracking, opening of construction joints, changes in leakage rates, and differential movements are all indications of possible overstressing. The overstressing may occur along the foundation because of differential or extreme foundation movements or at any location in the concrete mass of a dam where stresses are excessive. The overstressing may be due to unusual external loading conditions, temperature variations, contraction joint grouting pressures, foundation movement, or excessive uplift pressure in the foundation or along unbonded lift lines.

The amount of displacement associated with structural cracking often varies along the length of a structural crack. This variation usually occurs because a portion of the dam may have moved in relation to the original alignment. In any case, the presence of structural cracks could be an indication of progressive failure of the abutment, the foundation, or the dam itself. The inspector should record the location of the structural cracking, as well as the direction, width, and depth of the crack(s). Qualified professional assistance should be obtained if structural cracks are identified.

Shrinkage cracks often occur when irregularities or pockets in the abutment contact are filled with concrete and not allowed to cure fully prior to placement of adjacent portions of the dam. Subsequent shrinkage of the concrete may lead to irregular cracking at or near the abutment. Shrinkage cracks are also caused by temperature variation. During winter months, the upper portion of the dam may become significantly colder than those portions that are in direct contact with the reservoir water. This results in cracks, which extend from the crest for some distance down each face of the dam. These cracks will probably be at construction joints, if provided. Shrinkage cracks may also be a sign that certain portions of the dam are not carrying a load. The total compressive load must then be carried by a smaller percentage of the structure. It may be necessary to restore load-carrying capability by grouting affected areas.

Construction joints are provided to accommodate volumetric changes, which occur in the structure after concrete placement, and are referred to as "designed" cracks. These joints are so constructed that no bond or reinforcing, except non-bonded waterstops and dowels, extend across the joint. Cracking at construction joints is common, and typically results in spalling and minor leakage. The inspector should examine all joints and look for cracking, spalling, and seepage.

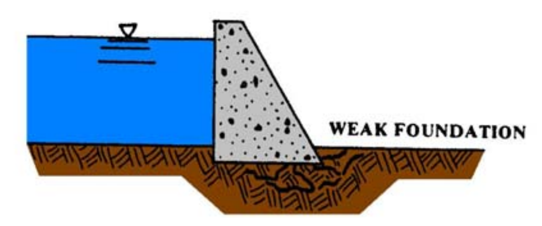


Figure 7-9a A weak foundation may result in foundation and concrete cracking.

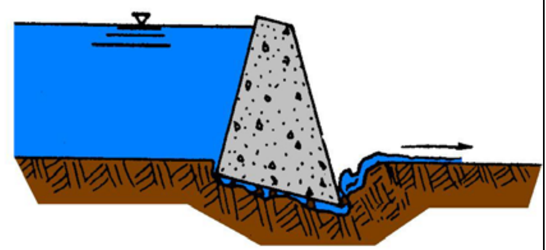


Figure 7-9b Weak foundation soils may result in dam movement and seepage.

Leakage through cracks in concrete dams, although unsightly, is not usually dangerous, unless accompanied by structural cracking. The worst effect may be to promote minor deterioration due to the elements through freeze-thaw action. Increases in seepage could indicate that materials are being leached from the dam and carried away by the flowing water. Decreases in seepage may also occur as mineral deposits are formed in the seepage channel. In neither case is the condition inherently dangerous. Detailed analysis of the problem may be required before it can be determined that repair is necessary for other than cosmetic reasons.

Cracks in the abutments and foundation of a dam may indicate a weak soil or rock zone, settlement due to consolidation, piping of soils or soluble rock from around or beneath the dam, or an overstressing caused by seismic activity or the load of the dam and reservoir. Foundation failure may allow the dam to start to move because of the force of the water behind the structure. In the worst-case scenario, the dam may collapse and allow the water to be released from the reservoir (see Figures 7-9a and 7-9b). The inspector should look for signs of weak foundations, including cracking, dam movement, foundation seepage, and wet, soft foundation soils.

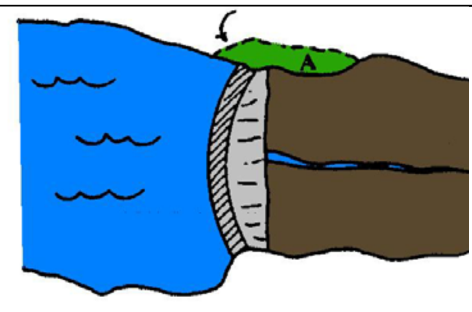


Figure 7-10a A weak area in the left abutment is subjected to large stresses from this arch dam.

Cracks across a stilling basin or the downstream toe of a concrete gravity dam may indicate sliding of the dam, excessive uplift, or damage from seismic activity. Abutment cracking is of particular concern with concrete arch dams since the loadings on the dam are concentrated at the abutments. The inspector should examine downstream appurtenant structures and abutment contact areas for signs of potential problems.

Concrete dams transfer substantial loads to the abutments and foundation. Although the concrete of the dam may endure, the natural terrain may crack, crumble, or move in a massive slide. If this occurs, support for the dam will be lost, and the dam will fail. Fault planes or weaknesses in the abutment may deteriorate with time, resulting in movement of the natural material in the abutment. Structural cracks in the concrete will be induced as a result of the movement in the abutment. This situation creates the potential for failure of all or a portion of the concrete structure, resulting in the release of reservoir water (see Figures 7-10a, b, and c). If the inspector observes structural cracking, he/she should carefully examine the foundation and abutments for signs of geological stresses or movement. Impending failure of the foundation or abutments is difficult to detect because initial movements are often very small.

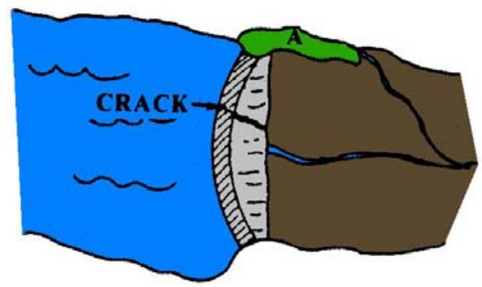


Figure 7-10b Movement of the abutment causes structural cracking in the dam.

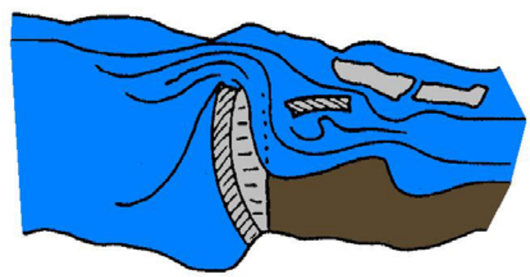


Figure 7-10c Continued abutment movement results in a dam breach.

The inspector should learn to recognize structural cracks that may affect the safety of the dam. A structural crack compromises the integrity of a concrete structure and therefore may pose a safety problem. In appearance, a structural crack may be:

- Diagonal or random with abrupt changes in direction
- Wide (greater than 0.25 in.), with a tendency to increase in width
- Adjacent to concrete that is noticeably displaced
- Occasionally narrow and diagonal, indicating inadequate design for shear stresses
- Long, single or multiple diagonal cracks with displacement and misalignment

The inspector should always look for seepage in or out of cracks. Water from seepage or leakage may compound the problem, leading to further degradation, including:

- The development of excessive hydrostatic pressures on some portions of the structure
- Attacking the concrete chemically
- Freeze-thaw damage to concrete
- Erosion or solution of the foundation material

- Leaching of the concrete

If cracking is observed during a visual inspection of a concrete dam, the inspector should take the following actions:

- Photograph and record location, depth, length, width, and offset of the cracks. Note prominent cracks, cracking over large areas, and the trends for particular cracks.
- Look for structural damage, including misalignment, settlement, vertical and horizontal displacement.
- Look for any surrounding cracks.
- Classify and describe the cracks using the terminology defined earlier and that shown on Table 7-2.

Table 7-2
Description of Cracks

Individual Cracks	Pervasive Cracks
- Direction - Width - Depth	- Pattern Cracks - D-Cracks - Checking
Hairline Cracks	**Structural Cracks**
- Individual Cracks - Pervasive Cracks	- Individual Cracks are typical

- If extensive new cracking is observed, consider initiating a crack survey to thoroughly document all cracks in the structure and their characteristics. Contact a qualified dam safety professional if there is uncertainty about the severity of cracking or if the following conditions are observed:
  - A major new crack
  - A crack(s) that has changed significantly since the last inspection
  - Cracks indicating movement that might be detrimental to the structure or to equipment operation
  - Significant leakage
  - Look for evidence of seepage or saturated soils in or below the cracks. Also, look for signs of foundation soil erosion. If there is an excessive amount of water flowing through a crack, recommend repairs. Check with a concrete specialist to identify appropriate repair procedures.
- Determine if other dam structures, such as the spillways or outlets, could be affected by the cracking.
- Closely monitor the cracks for changes.
- Try to determine the cause of the cracking; this can help identify effective corrective actions.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe or gets progressively worse. Serious cracking or repair operations may require lowering the reservoir level.
- Recommend appropriate corrective action be taken to repair, monitor, or replace the damaged areas. The recommended corrective actions should be consistent with the inspector's training and experience.

If instrumentation has been installed to monitor serious cracks, the data may supply reasons for the cracking. Measurements of leakage and movement are particularly important for evaluating cracks, as well as for evaluating joints, which also are subject to leakage and movement. Reading of an established monitoring network should be performed on a regular basis.

7.4 DETERIORATION

Deterioration is any adverse change on the surface or in the body of concrete dams that causes the structure to separate, break apart, or lose strength. A concrete structure cannot be expected to perform properly if it is deteriorated. The term, deterioration, is most commonly used in reference to the general condition of the concrete, and can result in the complete destruction of the material. The amount of deterioration, which has occurred in the concrete, is gaged with respect to its original condition. Deterioration is normally due to the forces of nature such as wetting and drying, freezing and thawing, oxidation, decay, and erosive forces of wind and water. Activities of humans can also contribute to deterioration by altering the chemical composition of water through application of chemicals on or near a dam, and by virtue of the use of the dam (mine tailings, waste storage or retention, and product storage). A subjective evaluation of the extent and possible effects of deterioration should be made. Sometimes deterioration will be complete enough to result in other detrimental conditions such as structural failures of concrete because of reinforcing corrosion. Table 7-3 lists common types of concrete deterioration.

Table 7-3
Common Types of Concrete Deterioration

- Disintegration
- Scaling
- Spalling
- Popouts
- Pitting
- Efflorescence
- Drummy concrete
- Faulty concrete mixes
- Chemical attack
    - Sulfate attack
    - Acid attack
    - Alkali-aggregate reaction
- Metal corrosion
- Erosion
- Joint deterioration
- Cavitation
- Surface defects

The inspector should use the terms listed on Table 7-3 to describe concrete deterioration. Many of the terms are interrelated, with one type of deterioration producing one or more other types. The use of common terminology will help reviewers to better understand the defects and problems.

Most concrete structures in Indiana experience some form of deterioration due to the severe nature of the climate and the dam environment. Most forms of concrete deterioration develop over a relatively long period of time with visual warning signs. Therefore, there is usually sufficient time to repair the structure before total failure occurs. The most common concrete defects on Indiana dams are normally caused by alkali-aggregate reaction, low aggregate strength, poor design or mix placement, and weathering. The inspector must be able to determine the cause and nature of the deterioration to be able to recommend corrective action.

Deterioration of concrete may be caused by many factors, including weathering, mechanical impacts, internal pressure, drying shrinkage, thermal stress, chemical action, leaching by water seepage, poor concrete mixes, poor concrete design, and freeze-thaw action. Water seeping through cracks in concrete usually leaches calcium from the concrete and forms white, calcium carbonate deposits on the concrete surfaces. It may be difficult to isolate the specific cause for concrete deterioration. If the inspector is not sure, he/she should obtain qualified professional help, or define the potential cause within a range of two or three possible causes. Sometimes, more than one mechanism may be involved. For example, cracking from thermal stress or drying shrinkage may lead to freeze-thaw action or leaching by water seepage.

Figure 7-11 Calcium carbonate deposits on the downstream face of a concrete dam as a result of water seepage.

Severe deterioration can result from a chemical reaction between alkali present in cements and certain forms of silica present in some aggregates. This chemical reaction produces byproducts in the form of silica gels, which cause expansion, and loss of strength within the concrete. Alkali-aggregate reaction is characterized by certain observable conditions, such as random cracking, and by excessive internal and overall expansion or swelling. Additional indications are a gelatinous exudation and whitish amorphous deposit on the surface, and lifeless, chalky appearance of the freshly fractured concrete. The inspector should look for these signs of alkali-aggregate reaction and record the location, extent, and physical characteristics of them. The white exudation from alkali-aggregate reaction should not be confused with white calcium carbonate deposits that are very common on concrete dams as a result of seepage leaching the calcium from the concrete. Table 7-4 describes common signs of alkali-aggregate reaction.

Table 7-4

<u>Early Indicators of Alkali-Aggregate Reaction</u>

- Pattern cracking, usually in areas exposed to wet-dry cycles, such as:
  - Parapets
  - Piers
  - Top of a dam
- Efflorescence
- Incrustation
- White rings around aggregate particles
- Gel-like substance exuded at:
  - Cracks
  - Pores
  - Openings
- Swelling of concrete

<u>Signs of Severe Alkali-Aggregate Reaction</u>

- Disbonding of blocks at lift lines
- Binding of gates
- Severe cracking
- Loss of strength and ultimate failure of the structure

Alkali-aggregate reaction is a chemical reaction that takes place in the presence of water. Surfaces exposed to the elements or dampened as a result of through dam seepage will demonstrate the most rapid deterioration. Once suspected, the condition can be confirmed by a series of tests performed on cores drilled from the dam. Although the process of deterioration is gradual, alkali-aggregate reaction cannot be economically corrected by any means now known. Continued deterioration often requires total replacement of the structure. If a highly active aggregate is used without proper low-alkali cement, the reaction between the aggregate and cement can cause swelling of the mass concrete, creating surface cracking and deterioration. This expansion of the concrete can also cause binding of gates, valves, and operating equipment, and deterioration of the concrete at metal-work supports.

Alkali-aggregate reaction can also lead to deterioration well into the mass of the concrete dam by disbonding blocks along construction joints. The reduction of strength resulting from disbonding, combined with a buildup of hydrostatic pressure along the open construction joints can affect the integrity of the dam. Besides alkali-aggregate reaction, deterioration of concrete can also be caused by other chemical reactions such as inorganic acids, sulfates, and other salts.

Low aggregate strengths or poor bonding characteristics of cement can produce low-strength concrete, which can cause cracking, spalling, or areas of distress in a dam. Aggregates with high absorption characteristics are highly susceptible to freeze-thaw damage. Aggregate, which has been contaminated by silt, clay, mica, coal, wood fragments, organic matters, chemical salts, or surface coatings, will produce concrete of low strength and durability. Minerals in the mixing water can also prevent the production of sound concrete.

Disintegration by weathering is caused mainly by the disruptive action of freezing and thawing, and by expansion and contraction, under restraint, resulting from temperature variations, and alternate wetting and drying. The effect of freeze-thaw action on a concrete dam is usually concentrated near the concrete surface and within exposed structural members. Parapets, cantilevers, top of dam roadway surfaces, stilling basin walls, tunnel or adit portals, and exposed decks and slabs are the most common areas affected by freeze-thaw action. Freeze-thaw action will not normally constitute a dam safety problem except when concrete associated with the water passages, mechanical equipment, or emergency access is affected. The effects of freeze-thaw action, like that of alkali-aggregate reaction, consist of surface deterioration and pattern cracking and can easily be identified by visual inspection. It is, however, sometimes difficult to distinguish between freeze-thaw and alkali reaction except by laboratory tests.

Deterioration of concrete can also result from the soluble products in the concrete being removed by leaching due to faulty concrete or the leachate being highly corrosive. Mineral deposits on the concrete surfaces usually indicate this type of disintegration.

Concrete deterioration can also occur from erosion. The principal causes of erosion of concrete surfaces are cavitation, movement of abrasive material by flowing water, abrasion and impact of traffic, wind blasting, and impact of flowing. Erosion, being a surface type of deterioration, is usually easily identified by a visual examination and its cause is usually evident. Erosion often produces a smooth, polished appearance of the aggregate within the concrete mass.

Surface defects are other concrete deficiencies that may not be progressive in nature; that is, they do not necessarily become more extensive with time. Surface defects are usually shallow and do not normally present an immediate threat to the structure. Most concrete structures typically show signs of surface defects. However, they may make the concrete more susceptible to more significant deterioration. Table 7-5 lists common types of surface defects on concrete structures.

Table 7-5
Common Surface Defects on Concrete Structures

● **Honeycomb:**	Voids in spaces between coarse aggregate particles.
	Cause - Poor construction practices: segregation due to improper placement or inadequate vibration.
● **Stratification:**	Separation into horizontal layers, with smaller material concentrated near the top. Possible results include nonuniform strength, weak areas, and disbonding of lifts.
	Cause - Overly wet or over-vibrated concrete, poor interlayer consolidation {vibration} or cold joints in placement.
● **Form Slippage:**	Slightly offset blocks, uneven joints and surfaces.
	Cause - Form movement during placement and vibration.
● **Stains:**	Discoloration
	Cause - Deposits from runoff water, corrosion of exterior steel, spilled construction materials, or curing water with staining qualities.
● **Impact Damage:**	Marred or spalled surfaces.
	Cause - Blows from moving trucks, boats, cranes, or debris.

Surface defects may include:

- Shallow deficiencies in the surface of the concrete
- Textural defects resulting from improper construction techniques
- Localized damage to the concrete surface

If concrete deterioration is observed during a visual inspection of a concrete dam, the inspector should:

- Photograph and record location, type, and extent of the deterioration. Note prominent features, and whether cracking is also present.
- Look for structural damage, including misalignment, settlement, vertical and horizontal displacement.
- Look for any surrounding damage to structures or foundation. The inspector should look closely for changes in the spillways and outlet structures that may be affected by structural damage to the dams. Items to inspect for include vertical, horizontal and lateral displacements, structural cracking, and tilting of spillway walls.
- Classify and describe the deterioration using the terminology previously defined.
- If deterioration is extensive, consider initiating a condition survey or surface mapping to thoroughly document all problems in the structure and their characteristics. Contact a qualified dam safety professional if there is uncertainty about the severity of deterioration.
- Look for evidence of seepage or saturated soils in or below the dam and on the abutments. Also, look for sign of foundation soil erosion. If there is an excessive amount of water, or water, which cannot be handled by the drainage system, is flowing through a crack, recommend repairs. Check with a concrete specialist to identify appropriate repair procedures.
- Determine if other dam structures, such as the spillway or outlet, could be affected by the deterioration that is observed.
- Closely monitor the problems for changes.
- Try to determine the cause of the deterioration; this can help identify effective corrective actions.

- Consult a qualified dam safety professional to determine the cause of the problem if it is severe or gets progressively worse. Serious deterioration or repair operations may require lowering the reservoir level.
- Recommend appropriate corrective action be taken to repair or to replace the damaged spillway or outlet areas. The recommended corrective actions should be consistent with the inspector's training and experience.

Although outlet system deterioration is usually not a problem at concrete dams, the frequency of such damage is higher due to greater average hydraulic head. Visual inspection of the outlet system should be emphasized during inspection of tall concrete dams.

7.5 SPECIAL INSPECTION TECHNIQUES AND REQUIREMENTS

Access and safety are special concerns that need to be planned for in advance of a visual inspection. The conditions normally encountered at concrete dams make it very difficult to gain close access to all features.

The faces of concrete dams are often near vertical, and the site is commonly a steep-walled rock valley. Access to the downstream face, toe area, and abutments may be difficult and usually requires special safety equipment such as safety ropes, or a boatswain's chair. Close visual inspection of the upstream face may also require a boatswain's chair or a boat. Without this equipment, visual inspection of all surfaces of the dam and abutments may not be possible.

Figure 7-12 Concrete dams are usually difficult to inspect.

Figure 7-13 Access to this in-channel concrete dam is dangerous.

A boat may be required to access the upstream face that is above the water. In-channel dams such as low head dams, and areas downstream of large outfalls are very dangerous and require extreme caution during visual inspections. The high velocity water current, whirlpools, hydraulic jumps, and eddies that form in these areas can create conditions that trap and sink boats and swimmers. The inspector should always wear life preserver jackets when using a boat. Experienced scuba divers are required if the submerged portion of the upstream face must be inspected. Radio communication between the diver and an experienced inspector on the surface is preferred during this exercise.

Regular visual inspection with a pair of powerful binoculars can initially identify areas where change from surrounding areas is occurring. When these changes are noted, a detailed close up inspection should be performed. Any questionable condition requires immediate evaluation by a qualified dam safety professional. Since the failure of concrete dams can occur suddenly, even a hint of a problem must be evaluated.

Another technique that can be used is videotaping of the entire structure. A high power zoom lens can be used to get close up video footage of the dam faces and discharge structures. The tapes can then be closely examined in the office for visual problems. Problems that are detected may then require closer visual inspection in the field. Problems that may be encountered with this technique include gaining access to points where filming will be effective, and obtaining full and complete coverage.

CHAPTER 8.0

INSPECTION OF GENERAL AREAS

8.0 INSPECTION OF GENERAL AREAS

The inspector should examine other areas around the dam and reservoir while performing routine inspections. An awareness of the complete dam environment will help the owner maintain the dam and be able to make improvements if conditions warrant. The following features and areas should be inspected during every routine dam inspection:


Figure 8-1 Shoreline areas and upstream watersheds should be visually inspected.

- Access
- Shoreline
- Reservoir area
- Submerged areas
- Watershed and tributary channels
- Mechanical and electrical systems
- Instrumentation
- Retaining structures
- Downstream hazards
- Downstream channel obstructions
- Upstream and downstream dams
- Bridge pier alignment and settlement
- Natural features, such as springs, sinkholes, rock outcrops

The inspector should examine all of these features and areas and record any changes or concerns in the inspection report. Photographs should be taken of problem conditions, and measurements of some problems may need to be made, such as slides on shoreline slopes, or cracks in access roads. Measurements and photographs will allow the inspector to monitor changes from one inspection to the next. Recent aerial photographs are very helpful in evaluating changing conditions in the upstream and downstream watersheds. The dam owner should be alerted to any conditions that may present a potential safety hazard. Deteriorated access roads, unauthorized activities (dirt bikes, 4-wheelers, etc), large landslides, upstream and downstream development, and severe sediment buildup are potentially hazardous concerns.


Figure 8-2 This dam has access to and over the embankment, however it may not be able to support heavy equipment.

Access to the dam, the reservoir, and the appurtenant works is important for a number of reasons, including dam maintenance, dam inspections, dam emergencies, and use of the dam and reservoir for its intended purpose. The inspector should visually check all adjacent roads and access roads to the dam and crest and assess them for emergency access potential. He/she should note any deterioration and obstructions that may be present, and record them in the inspection report. Photographs should be taken for damaged road sections, and corrective measures recommended.

Figure 8-3 This reservoir has severe shoreline erosion due to inadequate vegetation.

The shoreline and reservoir area should be checked for erosion, landslides, cracks, whirlpools, debris, burrowing animals, sediment buildup, and man-made changes and structures along the shore. Landslides into the reservoir can reduce the storage capacity which, in the worst case, may cause the dam to overtop during severe storm events. Signs of landslides include embankment cracking, scarps, and sloughs. Steep slopes along the shoreline are particularly vulnerable to slides. The inspector should also look for sign of seepage from slope areas. Whirlpools may indicate leaks or piping in the bottom of reservoir or along submerged outlets. Burrowing animals should be monitored because they may migrate to the embankment area where they may cause serious harm. Erosion along the shoreline will result in additional sediment entering the reservoir and filling up water space, as well as reducing the available reservoir area.

Figure 8-4 Excessive vegetation in reservoir almost completely conceals the spillway riser.

The reservoir submerged areas should be checked for sediment (when possible), debris, and excessive vegetative growth, including algae. Sediment from upstream areas is an ongoing problem in most reservoirs, and is very difficult, if not impossible to stop. When sediment deposits become severe, they should be removed; the usual method is dredging. Although sediment buildup is a concern because it diminishes the value and use of the reservoir, it normally does not affect the dam's stormwater storage capacity unless the sediment levels rise above the normal water level. Algae are not normally a safety concern, but they make the reservoir unsightly. Safe treatments for algae are available. Algae are often caused by excessive soil nutrients being carried into the reservoir by stormwater runoff, usually from farm fields and lawns.

If the dam or reservoir includes mechanical and electrical features, they should be inspected for disrepair and deterioration. This includes items previously discussed, including spillway gates, sluice gates or valves, stoplogs, flashboards, relief wells, and siphons. It also includes emergency power sources, guardrails along roads, signage, buried cables and utilities, outfall pipes, conduits entering the reservoir, etc. All mechanical and electrical equipment should be operated at least once per year, and preferably more often. The tests should be conducted by the owner or operator, and should include the full operating range of the equipment 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, and all operating instructions and manuals should be checked for clarity and maintained in a secure, but readily accessible location.

Figure 8-5 Downstream view of gates on a central-Indiana dam.

Figure 8-6 Badly deteriorated wall along spillway discharge channel.

The inspector should always check instrumentation that may be used to monitor dam performance or dam safety concerns. This includes items such as piezometers, inclinometers, tiltmeters, weirs, flumes, flow meters, etc. This equipment should be inspected to make sure it is in good condition and has not deteriorated or been damaged.

Retaining walls are often constructed along shorelines, discharge areas, and other dam areas to help stabilize steep slopes, or to support features such as roads, buildings, and parking lots. The retaining walls should be checked for potential stability concerns, such as structural cracking, horizontal displacement or tilting, settlement, erosion of the foundation area, and uncontrolled seepage. The failure of a retaining wall may create potential safety hazards, especially if they support parking areas and roads, or if the failure results in a large landslide into the reservoir.

The upstream watershed should be checked primarily for new development which can increase the amount of runoff that enters the reservoir. Impervious areas, such as parking lots, rooftops, and roads will dramatically increase the amount and rate of runoff. Construction sites that disturb large areas of soil will also result in increased runoff as well as increased sediment. New dams in the upstream watershed may also impact the dam that lies downstream. Dams and reservoirs will alter the runoff patterns and the timing of the peak runoff rates. Urban development in the watershed can increase the size of flood peaks and the volume of runoff, thereby making a previously acceptable spillway inadequate. The dam hydrologic and hydraulic analyses may have to be updated if the upstream development is significant, or if a new dam is constructed upstream. Improvements to the dam appurtenant facilities, such as spillway size, outfall linings, and embankment top elevation may have to be implemented if the development creates a significant increase in inflow to the reservoir.

Figure 8-7 Downstream tailwater inundates toe of dam embankment.

Downstream development may create new safety hazards for the dam owner in the event that the dam would fail. New houses, roads, and other buildings that are occupied by people may change the hazard classification of the dam if these features are within the area which would be inundated if the dam failed. New features must be reported to the owner immediately upon their identification.

Downstream channel obstructions, including dams, can have an impact on the discharge from the dam if the new facilities are close enough. Tailwater that backs up from dams and other obstructions during floods, may reduce the discharge capacity of the upstream dam, especially if the upstream dam has a conduit spillway. The hydrologic and hydraulic calculations for the new features, if performed, should take the upstream dam into account. Tailwater from obstructions should be carefully evaluated to determine if it will impact the upstream dam discharge structures.

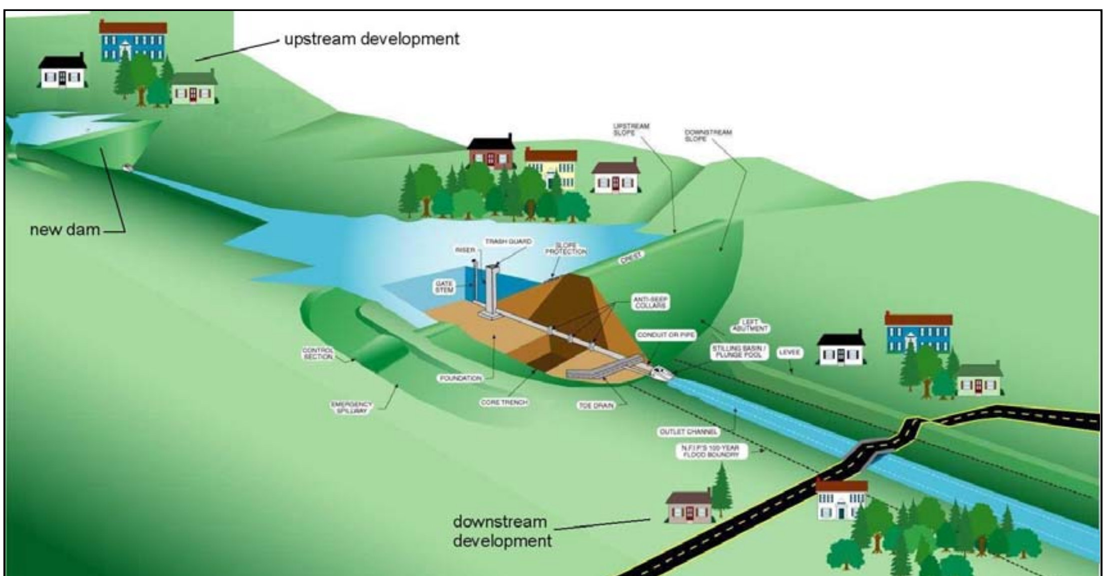


Figure 8-8 Sketch of upstream and downstream development features that can impact the operation of a dam.

APPENDICES

APPENDIX A

GLOSSARY

GLOSSARY

AASHTO Classification - The official classification of soil materials and soil aggregate mixtures for highway construction used by the American association of State Highway and Transportation Officials.

Acre-Foot - The volume of water that will cover 1 acre to a depth of 1 ft.

Abutment - The part of a valley side (wall) against which a dam is constructed. An artificial abutment is sometimes constructed as a concrete gravity section, to take the thrust of an arch dam where there is no suitable natural abutment. Right and left abutments are those on respective sides of an observer looking downstream.

Aggregate - (1) The sand and gravel portion of concrete (65 to 75% by volume), the rest being cement and water. Fine aggregate contains particles ranging from 1/4 in. down to that retained on a 200-mesh screen. Coarse aggregate ranges from 1/4 in. up to 11/2 in. (2) That which is installed for the purpose of changing drainage characteristics.

Air Vent - A pipe designed to provide air to the outlet conduit to reduce turbulence and prevent negative pressures during release of water. Extra air is usually necessary downstream of constrictions.

Alluvial Soils - Soils developed from transported and relatively recently deposited material (alluvium) characterized by a weak modification (or none) of the original material by soil-forming processes.

Alluvium - A general term for all detrital material deposited or in transit by streams, including gravel, sand, silt, clay, and all variations and mixtures of these. Unless otherwise noted, alluvium is unconsolidated.

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

Anti-Vortex Device - A facility placed at the entrance to a pipe conduit structure, such as a drop inlet spillway or hood inlet spillway, to prevent air from entering the structure when the pipe is flowing full.

Appurtenant Structures or Works - Auxiliary features of a dam that are reasonably required for the safe and proper operation of the structure. The term may include each of the following: 1) the spillway system; 2) outlet works; 3) gates and valves; 4) tunnels; 5) conduits; 6) levees; and 7) embankments.

Apron - A pad of non-erosive material designed to prevent scour holes developing at the outlet ends of culverts, outlet pipes, grade stabilization structures, and other water control devices.

Arch Dam - A concrete or masonry dam that is curved so as to transmit the major part of the water pressure to the abutments.

As-Built Drawings - Plans or drawings portraying the actual dimensions and conditions of a dam, dike, or levee as it was built. Field conditions and material availability during construction often require changes from the original design drawings.

ASTM - American Society for Testing Materials, an association that publishes standards and requirements for materials used in the construction industry.

Atterberg Limits - Method used to describe the consistency of fine-grained soils with varying degrees of moisture content. Depending on the amount of moisture present, fine-grained soils can be categorized by one of four states: solid, semisolid, plastic, and liquid. The Atterberg Limits define the transition between each of these states as: (1) the shrinkage limit, which is the moisture content at which the transition from solid to semisolid state takes place; the plastic limit, which is the moisture content at which the transition from semisolid to plastic state takes place; and the liquid limit, which is the moisture content at which the transition from plastic to liquid state takes place. The **Plasticity Index** is the numerical difference between the liquid limit and the plastic limit of soil, which is the range of moisture content within which the soil remains plastic.

Auxiliary Spillway - See Spillway.

Axis of Dam - The horizontal centerline of a dam in the longitudinal direction.

Backwater - The rise in water surface elevation caused by some obstruction such as a culvert, narrow bridge opening, inefficient channel, dams, buildings or fill material that limits the area through which the water shall flow. Backwater reduces the capacity of a waterway or conduit.

Base Flow - Stream discharge derived from groundwater sources as differentiated from surface runoff. Sometimes considered to include flows from regulated lakes or reservoirs.

Beaching - The removal by wave action of a portion of the upstream (reservoir) side of the embankment and the resultant deposition of this material farther down the slope. Such deposition creates a relatively flat beach area.

Bedrock - The more or less solid rock in place either on or beneath the surface of the earth. It may be soft, medium, or hard and have a smooth or irregular surface.

Benchmark - A marked point of known elevation from which other elevations may be established.

Bentonite - Highly plastic clay consisting of the minerals, montmorillonite, and beidellite that swell extensively wet. Often used to seal soil to reduce seepage losses.

Berm - A horizontal step or bench in the upstream or downstream face of an embankment dam. It is sometimes called a bench.

Blanket - Drainage Blanket - A drainage layer placed directly over the foundation material, typically to control water movement to prevent soil particle migration and erosion. **Blanket Drain** - A drain that extends in a generally horizontal direction (much like a blanket) under a relatively large area of the downstream portion of the embankment, intercepts seepage through the embankment and the foundation, and pre- vents further saturation of the downstream toe. **Grout Blanket** - See Consolidation Grouting. **Upstream Blanket** - An impervious layer placed on the reservoir floor upstream of a dam. In the case of an embankment dam, the blanket may be connected to the impermeable element in the dam.

Boil - A disturbance in the surface layer of soil caused by water escaping under pressure from behind a water-retaining structure such as a dam or a levee. The boil may be accompanied by deposition of soil particles (usually granular) in the form of a cone-shaped ring (miniature volcano) around the area where the water escapes.

Borrow Area - A source of earth fill material used in the construction of embankments or other earth fill structures.

Breach - An opening or a breakthrough of a dam resulting in a release of water. A **controlled breach** is the deliberate, controlled removal of embankment material to release water from the reservoir at a controlled rate. An **uncontrolled breach** is typically caused by rapid erosion of a section of earth embankment by water or other natural, uncontrolled forces.

Buttress Dam - A dam consisting of a watertight upstream face supported at intervals on the downstream side by a series of buttresses.

Cavitation - Wear on hydraulic structures where a high hydraulic gradient is present. Cavitation is caused by the abrupt change in direction and velocity of the water so the pressure at some points is reduced to the vapor pressure and vapor pockets are created. These pockets collapse with great impact when they enter areas of higher pressure, producing very high impact pressures over small areas that eventually cause pits and holes in the surface. Noises and vibrations may be evident during high flows.

Channel - A portion of a natural or artificial watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a defined bed and banks that serve to confine the water.

Channel Stabilization - Protecting the sides and bed of a channel from erosion by controlling flow velocities and flow directions using jetties, drops, or other structures and/or by lining the channel with vegetation, riprap, concrete, or other suitable lining material.

Chute - A high-velocity, open channel (usually paved) for conveying water down a steep slope without erosion.

Clay - (1) Soil fraction consisting of particles less than 0.002 mm in diameter. (2) A soil texture class that is dominated by clay or at least has a larger proportion of clay than either silt or sand. Clay exhibits the property of cohesion when the moisture content is below the liquid limit and above the plastic limit.

Cofferdam - A temporary structure enclosing all or part of a construction area so that construction can proceed in a dry area. A "diversion cofferdam" diverts a river into a pipe, channel, or tunnel.

Cohesion - Property of unconsolidated fine-grained soil by which the particles stick together by surface forces. Cohesion is a property that permits soil to be molded or rolled into shapes without crumbling.

Cohesive Soil - A sticky soil such as clay or silt exhibiting cohesion; its shear strength is approximately half it unconfined compressive strength. When unconfined, it has considerable strength when air-dried and significant strength when saturated.

Conduit - A closed channel for conveying discharge through, under or around a dam. A pipe and a box culvert are conduits.

Consolidation Grouting (Blanket Grouting) - The injection of grout to consolidate a layer of the foundation, resulting in greater impermeability and/or strength.

Construction Joint - The interface between two successive placings or pours of concrete where a bond, not permanent separation, is intended.

Contour - An imaginary line on the surface of the earth connecting points of the same elevation. May also be called a contour line. Topographic maps are developed to depict contour lines.

Control Section - The component of a spillway which regulates the outflows from the reservoir. A control structure limits or prevents outflows below fixed reservoir levels and regulates releases when the reservoir rises above that level.

Core - The impervious or relatively impervious material forming the central part of a dam or embankment. Where a dam has a core, the outer zones are usually comprised of more pervious materials. Some dams are constructed entirely of a relatively homogeneous, impervious material with no distinct core.

Core Wall - A wall built of impervious material, usually concrete or asphaltic concrete, in the body of an embankment dam to prevent leakage.

Corrosion - The chemical attack on a metal by its environment. Corrosion is a reaction in which metal is oxidized.

Crest Length - The length of the top of a dam, excluding the length of spillway unless otherwise noted, powerhouse, navigation lock, fish pass, etc. where these structures form part of the length of a dam. If detached from a dam, these structures should not be included.

Crest of Dam - The top of a dam (See Top of Dam).

Crest Width or Top Thickness - The thickness or width of a dam at the level of the top of the dam. In general, the term "thickness" is used for gravity and arch dams and "width" is used for other dams.

Crib Dam - A gravity dam built up of boxes, cribs, crossed timbers, or gabions and filled with earth or rock.

Crown of Pipe - The elevation of the top of pipe.

Cross Section - A “cut” across any structure, such as an embankment, to depict the composition or dimensions of the structure at the point of the cross section. It may be a graph or plot of ground elevation across a stream valley or a portion of it, usually along a line perpendicular to the stream or direction of flow.

Culvert - A closed conduit used for the conveyance of water under an embankment, roadway, railroad, canal or other impediment.

Cut - (1) A portion of land surface or area from which earth has been removed or will be removed by excavating. (2) The depth below the original ground surface to the excavated surface.

Cut-and-Fill - The process of earth grading by excavating part of a higher area and using the excavated material for fill to raise the surface of an adjacent lower area.

Cutoff - An impervious construction or material which reduces seepage or prevents it from passing through foundation material.

Cutoff Trench - A long, narrow excavation (keyway) constructed along the center line of a dam, dike, levee, or embankment and filled with relatively impervious material intended to reduce seepage of water through porous strata.

Cutoff Wall - A wall of impervious material (e.g., concrete, asphaltic concrete, steel sheet piling) built into the foundation to reduce seepage under the dam.

Dam – An artificial manmade barrier, including appurtenant works, built for impounding or diverting water. Dams may be constructed to retain normal runoff from streams and land surfaces, flood waters, water pumped from a stream or a well, and mining operations. Off-channel reservoirs may also have a dam to control the water elevation and discharge.

Dam Safety Professional - A dam safety professional is an engineer or geologist with specific expertise in the design, operation, and construction of dams and appurtenant works. A dam safety professional must have specific knowledge with the aspects of the dam under consideration; for example, an engineer or geologist with geotechnical or geological experience would be required to evaluate a slope stability or soil concern. Or, an engineer with hydrologic and hydraulic experience would be required to determine spillway capacity. A dam safety professional is qualified if he/she has specific dam-related experience relevant to the issues or concerns that are present at any particular dam. A qualified dam safety professional is required to supervise and prepare the Inspection Report for formal technical inspections on high hazard dams; current IDNR regulations for high hazard dams may require that a professional engineer registered in the state of Indiana make the formal technical dam inspections.

Design Flood - The largest flood that a given project is designed to pass safely. The reservoir inflow-discharge hydrograph used to estimate the spillway discharge capacity requirements and corresponding maximum surcharge elevation in the reservoir.

Design Life - The period of time for which a facility is expected to perform its intended function.

Design Pool Elevation (maximum design pool elevation) – The highest water level impounded by the dam resulting from the design storm event, assuming both of the following: 1) No: A) debris blockage; B) unplanned restrictions; or C) improper operation of the spillway; 2) Prestorm water level at the level of the principal spillway.

Design Storm - The depth of precipitation that is used to calculate the volume and time distribution of runoff from a watershed that a spillway system must safely pass without jeopardizing the safety of the dam. The depth of precipitation typically ranges from fifty percent (50%) to one hundred percent (100%) of probable maximum precipitation, depending upon the hazard classification.

Dewatering - The removal of water from a reservoir or other area.

Dike - An embankment used to confine, divert, or control water. Often built along the banks of a river to prevent overflow of lowlands; a levee.

Discharge - Usually the rate of water flow. A volume of fluid passing a point per unit time commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, or millions of gallons per day. The rate of water flowing out of a dam.

Divide (drainage) - The boundary between watersheds.

Division – The division of water of the Department of Natural Resources (IDNR).

Downstream Toe of Dam - The lowermost portion of the downstream face of a dam where the embankment intersects with the ground surface. For an embankment dam the lowermost portion of the upstream face is the upstream toe.

Drainage Area or Watershed - An area that drains naturally to a particular point on a stream. For dams, the upstream area that drains into the lake, including the lake.

Drainage Layer or Blanket - A layer of permeable material in a dam to relieve pore pressure or to facilitate drainage of fill (see Blanket).

Drainage - The removal of excess surface water or groundwater from land by means of ditches or subsurface drains. Also see Natural drainage.

Drainage Improvement - An activity within or adjacent to a natural stream or a man-made drain primarily intended to improve the flow capacity, drainage, erosion and sedimentation control, or stability of the drainageway.

Drains - 1) Relief Wells - A vertical well or borehole, usually downstream of impervious cores, grout curtains, or cutoffs, designed to collect and direct seepage through or under a dam to reduce uplift pressure under or within a dam. A line of such wells forms a drainage curtain. 2) A buried slotted or perforated pipe or other conduit (subsurface drain) or a ditch (open drain) for carrying off surplus groundwater or surface water.

Drawdown - The lowering of water surface level due to release of water from a reservoir.

Drop Inlet - A structure in which water enters over a horizontal lip, drops through a vertical or sloping shaft, and then discharges through a conduit to the receiving waters. It is also commonly referred to as a riser in dam construction. A drop inlet typically comprises three components: an overflow control weir, a vertical transition, and a closed discharge channel or conduit. (See Spillway.)

Duration - The time period of a rainfall event.

Embankment Dam (Fill Dam) - Any dam constructed of natural fill materials. **Earth Dam** (Earthfill Dam) - An embankment dam in which more than 50% of the total volume is formed of compacted fine-grained material obtained from a borrow area. **Homogeneous Earthfill Dam** - An embankment dam constructed of similar earth material throughout, except for possible inclusion of internal drains or drainage blankets; distinguished from a zoned earthfill dam. **Rockfill Dam** - An embankment dam in which more than 50% of the total volume comprises compacted or dumped pervious natural or crushed rock. **Rolled Fill Dam** - An embankment dam of earth or rock in which the material is placed in layers and compacted by using rollers or rolling equipment. **Zoned Embankment Dam** - An embankment dam, which is composed of zones of selected materials having different degrees of porosity, permeability, and density.

Emergency Action Plan (EAP) - A formal plan that identifies potential emergency conditions at a dam and outlines the procedures to follow to minimize property damage and loss of life. An EAP is needed to preplan the actions taken by the dam owner, Indiana Department of Homeland Security (IDHS) personnel, and local emergency officials during an emergency. The plan will help provide for timely notification, warning, and evacuation in the event of an emergency; it must be updated and practiced as conditions dictate. It is up to the dam owner to implement the EAP during an emergency.

Emergency Spillway - See Spillway. Usually a vegetated earth channel used to safely convey flood discharges around an impoundment structure.

Energy Dissipater - A device used to reduce the energy of flowing water to prevent erosion.

Erodibility - Susceptibility to erosion.

Erosion - The wearing away of the land surface by water, wind, ice, gravity, or other geological agents. The following terms are used to describe different types of water erosion: **accelerated erosion** - erosion much more rapid than normal or geologic erosion, primarily as a result of the activities of man; **channel erosion** - an erosion process whereby the volume and velocity of flow wears away the bed and/or banks of a well-defined channel; **gully erosion** - an erosion process whereby runoff water accumulates in narrow channels and, over relatively short periods, removes the soil to considerable depths, ranging from 1-2 ft. to as much as 75-100 ft; **rill erosion** - an erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils (see Rill); **splash erosion** - the spattering of small soil particles caused by the impact of raindrops on wet soils; the loosened and spattered particles may or may not be subsequently removed by surface runoff; **sheet erosion** - the gradual removal of a fairly uniform layer of soil from the land surface by runoff water.

Face - The external surface of a structure, such as the surface of an appurtenance or a dam.

Filter (Filter Zone) - A band or zone of granular material that is incorporated into a dam and is graded (either naturally or by selection) so as to allow seepage to flow across or down the filter without causing the migration of material from zones adjacent to the filter. Filters and associated drains within an earthen embankment permit drainage or removal of liquids to avoid saturation of the downstream toe of the embankment and/or to control underseepage forces, while preventing the removal of finer-sized particles. Filters associated with erosion protection on slopes of dams or in channel linings prevent the removal of finer-sized particles by wave action or turbulence from beneath the larger-sized material (see blanket drain, and vertical or sloping filter).

Filter Blanket - A layer of sand and/or gravel designed to prevent the movement of fine-grained soils.

Filter Fabric - See Geotextile Fabric.

Flapgate - A device that allows liquids to flow in only one direction in a pipe. Backflow preventers are used on outlet pipes to prevent a reverse flow during flooding situations.

Flashboards - Individual lengths of timber, concrete, or steel anchored to the crest of a spillway to raise the retention water level but which may be quickly removed in the event of a flood either by a tripping device or by deliberately designed failure of the flashboard or its supports. To provide adequate spillway capacity, the flashboard must be removed before the floods occur, or they must be designed or arranged so that they can be removed while being overtoppped

Flood or Flood Waters - A general and temporary condition of partial or complete inundation of normally dry land areas from the overflow, the unusual and rapid accumulation, or the runoff of surface waters from any source.

Flood Frequency - A statistical expression of the average time period between floods equaling or exceeding a given magnitude. For example, a 100-year flood has a magnitude expected to be equaled or exceeded on the average of once every hundred years; such a flood has a 1% chance of being equaled or exceeded in any given year. Often used interchangeably with "recurrence interval".

Flood Peak - The highest stage or greatest discharge attained by a flood event, thus peak stage or peak discharge.

Flood Routing - The determination of the attenuating effect of storage on a flood passing through a valley, channel, or reservoir.

Flood Stage - The stage at which overflow of the natural banks of a dam or a stream begins.

Floodway - The channel of a river or stream and those portions of the flood plains adjoining the channel which are reasonably required to efficiently carry and discharge the peak flow of the 100-yr flood of any river or stream.

Flume - A constructed channel lined with erosion-resistant materials used to convey water on steep grades without erosion.

Foundation Drain - A pipe or series of pipes that collects groundwater from the foundation of a dam or the footing of structures to improve stability.

Foundation of Dam - The natural material on which the dam structure is placed.

French Drain - A drainage trench backfilled with a coarse, water-transmitting material; may contain a perforated pipe.

Gabion - A hollow cage or basket, usually of heavy wire, filled with stones or rock and used as a revetment or other protective device to sustain a wall, embankment, or channel.

Gallery - (a) A passageway within the body of a dam or abutment; hence the terms "grouting gallery", "inspection gallery", and "drainage gallery". (b) A long and rather narrow hall; hence the following terms for a power plant: "valve gallery", "transformer gallery", and "busbar gallery".

Gate - A device in which a leaf or member is moved across the waterway from an external position to control or stop the flow. **Bulkhead Gate** - A gate used either for temporary closure of a channel or conduit to empty it for inspection or maintenance or for closure against flowing water when the head difference is small, e.g., a diversion tunnel closure. Although a bulkhead gate is usually opened and closed under nearly balanced pressures, it nevertheless may be capable of withstanding a high pressure differential when in the closed position. **Crest Gate** (Spillway Gate) - A gate on the crest of a spillway to control overflow or reservoir water level. **Emergency Gate** - A standby or reserve gate used only when the normal means of water control is not available. **Fixed Wheel Gate** (Fixed Roller Gate, Fixed Axle Gate) - A gate having wheels or rollers mounted on the end posts of the gate. The wheels bear against rails fixed in side grooves or gate guides. **Flap Gate** - A gate hinged along one edge, usually either the top or bottom edge. Examples of bottom-hinged flap gates are tilting gates and fish belly gates, so-called due to their shape in cross section. **Flood Gate** - A gate to control flood release from a reservoir. **Guard Gate** (Guard Valve) - A gate or valve that operates fully open or closed. It may function as a secondary device for shutting off the flow of water in case the primary closure device becomes inoperable, but is usually operated under balanced pressure, no-flow conditions. **Outlet Gate** - A gate controlling the outflow of water from a reservoir. **Radial Gate** (Tainter gate) - A gate with a curved upstream plate and radial arms hinged to piers or other supporting structures. **Regulating Gate** (Regulating Valve) - A gate or valve that operates under full pressure and flow conditions to throttle and vary the rate of discharge. **Slide Gate** (Sluice Gate) - A gate that can be opened or closed by sliding it in supporting guides.

Gage - (1) A device for measuring precipitation, water level, discharge, velocity, pressure, temperature, etc. (2) A measure of the thickness of metal.

Geotextile Fabric - A woven or non-woven, water-permeable synthetic material used to trap sediment particles, prevent the clogging of aggregates with fine grained soil particles, or as a separator under road aggregate. It is also used as a filter.

Geotextile Liner - A synthetic, impermeable fabric used to seal impoundments against leaks.

Gradation - The distribution of the various sized particles that constitute sediment, soil, or other material, such as riprap.

Grade - (1) The slope of a road, a channel, or natural ground. (2) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared to a design elevation for the support of construction, such as paving or the laying of a conduit. (3) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation, or other land area to a smooth, even condition.

Gradient - (1) A change of elevation, velocity, pressure, or other characteristics per unit length. (2) Slope.

Grading - The cutting/or filling of the land surface to a desired slope or elevation.

Grassed Waterway - A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses and used to safely conduct surface water from an area.

Gravity Dam - A dam constructed of concrete and/or masonry that relies on its weight for stability.

Groin Area - The area at the intersection of either the upstream or downstream slope of an embankment and the valley wall or abutment.

Ground Cover (horticulture) - Low-growing, spreading plants useful for low-maintenance landscape areas.

Grout - A thin cement mortar used to fill voids, fractures, or joints in masonry, rock, sand and gravel, and other materials. As a verb it refers to filling voids with grout. Grout is usually applied under pressure.

Grout Curtain (Grout Cutoff) - A narrow barrier produced by injecting grout into a vertical zone, through the embankment, into the foundation to reduce seepage under a dam; or a grout barrier injected into the foundation before the dam is constructed.

Hazard Classification – The classification of a dam that reflects the potential for loss of life and property if an uncontrolled release of the structure's contents occurs. The Indiana classification includes high hazard, significant hazard, and low hazard.

Head - (1) The height of water above any plane of reference. (2) The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit would have to fall to release the average energy possessed. Used in various compound terms, such as pressure head or velocity head.

Head Loss - Energy loss due to friction, eddies, changes in velocity, elevation, or direction of flow.

Headwater - (1) The source of a stream. (2) The water upstream from a structure or point on a stream.

Homogeneous Earthfill - An embankment-type construction of more or less uniform earth materials throughout, except for possible inclusion of internal drains or blanket drains. The term is used to differentiate from a zoned earthfill embankment.

Hydraulic Jump - The abrupt rise in water surface that may occur in an open channel or stilling basin when water flowing at high velocity is retarded or suddenly slowed down.

Hydrograph - A graphic representation of discharge from a reservoir, or runoff from a watershed with respect to time for a particular point.

Hydrologic Cycle - The circuit of water movement from atmosphere to earth back to the atmosphere through various stages or processes, such as precipitation, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrology - The science of the behavior of water in the atmosphere, on the surface of the earth, and underground. A typical hydrologic study is undertaken to compute flow rates associated with specified flood events.

Hydromulching - The process of applying mulch hydraulically in a water medium.

Hydroseeder - The machine/equipment used to disseminate seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious - Not allowing infiltration.

Impoundment - Generally, an artificial water storage area, such as a reservoir, pit, dugout, sump, etc.

Inclinometer (Inclometer) - An instrument, usually consisting of a metal or plastic tube, inserted in a drill hole and a sensitized monitor either lowered into the tube or fixed within the tube. This measures at different points the tube's inclination to the vertical. By integration, the lateral position at different levels of the tube may be found relative to a point, usually the top or bottom of the tube, assumed to be fixed. The system may be used to measure settlement.

Infiltration - Passage or movement of water into the soil.

In situ - In the natural or original position. With respect to dams, in situ usually refers to the existing, undisturbed earth. For example, in situ spillways are spillways constructed within undisturbed ground, usually adjacent to the embankment fill. May be used as one word, “insitu.”

Intermittent Stream - A stream that does not maintain water in its channel throughout the year; it normally stops flowing at various times of the year.

Internal Erosion - See Piping.

Inundation Area (maximum breach inundation area) – The downstream area that would be affected by flooding from an uncontrolled release of a dam’s contents when: 1) the impoundment is at maximum design pool elevation; 2) the downstream area is flooded from the spillway discharge when the dam breaches; and 3) conditions exist that would result in the highest hazard potential for: A) property damage; or B) the possible loss of human life; if the dam fails.

Inundation Map - A map delineating the area that would be inundated in the event of a dam failure.

Invert - The inside bottom of a culvert or other conduit.

Karst - Topography formed over limestone, dolomite, or gypsum and characterized by sinkholes, caves, and underground drainage.

Keyway - A cutoff trench dug beneath the entire length of a dam to cut through soil layers that may cause seepage and possible dam failure. A keyway may also refer to benches excavated on existing ground for the purpose of creating a stable interface between the existing ground and fill placed in an embankment.

Laminar Flow - Flow at relatively slow velocity in which fluid particles slide smoothly along straight lines everywhere parallel to the axis of a channel or pipe.

Leakage - Uncontrolled loss of water by flow through a hole or crack. See Seepage.

Levee (Dike) - A long, low embankment usually built to protect land from flooding. If built of concrete or masonry the structure is usually referred to as a floodwall. The term "dike" is commonly used to describe embankments that block areas on a reservoir rim that are lower than the top of the main dam.

Lining - With reference to a canal, tunnel, shaft, or reservoir, a coating of asphaltic concrete, reinforced or unreinforced concrete, shotcrete, rubber or plastic to provide watertightness, prevent erosion, reduce friction, or support the periphery of the structure. May also refer to the lining, such as steel or concrete, of an outlet pipe or conduit.

Low-Level Outlet (Bottom Outlet or Sluiceway) - An opening at a low level from a reservoir generally used for emptying or for scouring sediment and sometimes for irrigation releases.

Loam - A soil textural classification in which the proportions of sand, silt, and clay are well balanced. Loams have the best properties for cultivation of plants.

Low Head Dam - A dam of low height (usually less than 15 feet) made of timbers, stone, concrete or some combination thereof that extends across a stream or channel.

Masonry - A dam constructed mainly of stone, brick, or concrete blocks that may or may not be joined with mortar. A dam having only a masonry facing should not be referred to as a masonry dam.

Maximum Breach Inundation Area – See Inundation Area.

Mean Depth - (1) Average depth. (2) Cross-sectional area of a stream or channel divided by its surface or top width.

Mean Velocity - Average velocity of a stream flowing in a channel or conduit at a given cross section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Mulch - A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Nappe - The lower surface, or underside, of a free falling stream of water, usually over a dam crest or weir.

National Geodetic Vertical Datum of 1929 (NGVD 1929) - The nationwide, Federal Elevation datum used to reference topographic elevations to a known value.

Natural Drainage - The flow patterns of stormwater run-off over the land in its pre-development state.

Non-cohesive Soil - Cohesionless soil consisting of single-grained or honeycombed particles that exhibit low shear strength when dry, and low cohesion when wet. Sand and gravel are examples of a non-cohesive soil.

Normal Depth - Depth of flow in an open conduit during uniform flow for the given conditions.

Normal Water Level (Normal Pool Level) - For a reservoir with a fixed overflow, the lowest crest level of that overflow. For a reservoir whose outflow is controlled wholly or partly by movable gates, siphons or other means, it is the maximum level to which water may rise under normal operating conditions, exclusive of any provision for flood surcharge.

Nutrient(s) - 1) A substance necessary for the growth and reproduction of organisms. (2) In water, those substances (chiefly nitrates and phosphates) that promote growth of algae and bacteria.

Occupied Quarters – A structure that is or may be used for any of the following: 1) Human Living Quarters. 2) Business. 3) Medical services. 4) Education. 5) Place of worship. 6) Public office. 7) Industrial facilities. 8) Permanent or temporary overnight lodging for humans.

Outfall - The point, location, or structure where wastewater or drainage discharges from a pipe or open drain to a receiving body of water.

Outlet - An opening through which water can be freely discharged from a reservoir, or the point of water disposal from a stream, river, lake, tidewater, or artificial. Used to drawdown the reservoir level in dams. Also referred to as a reservoir drain.

Outlet Channel - (Discharge Channel) A waterway constructed or altered primarily to carry water from man-made structures, such as dam spillways, smaller channels, tile lines, and diversions.

Overland Flow - Consists of sheet flow, shallow concentrated flow and open channel flow. The flow of stormwater runoff across the ground surface.

Parapet Wall - A solid wall built along the top of a dam for ornament, for the safety of vehicles and pedestrians, or to prevent overtopping.

Peak Discharge - The maximum instantaneous flow from a given storm condition at a specific location.

Percolation - The movement of water through soil.

Percolation Rate - The rate, usually expressed as inches per hour or inches per day, at which water moves through the soil profile.

Perennial Stream - A stream that maintains water in its channel throughout the year.

Permeability (soil) - The quality of a soil that enables water or air to move through it. It also refers to the rate at which water moves through soil. Usually expressed in centimeters per second, inches per hour or inches per day.

Permeability Rate - The rate at which water will move through a saturated soil. Permeability rates are classified as: **very slow** - less than 0.06 in./hr.; **slow** - 0.06 to 0.20 in./hr; **moderately slow** - 0.20 to 0.63 in./hr; **moderate** - 0.63 to 2.0 in./hr;

moderately rapid - 2.0 to 6.3 in./hr; **rapid** - 6.3 to 20.0 in./hr; **very rapid** - more than 20.0 in./hr.

Permittivity - The volumetric flow rate of water per unit cross-sectional area per unit head under laminar flow conditions, in the normal direction generally through a geotextile.

Pervious Zone - A part of the cross section of an embankment dam comprising material of high permeability.

pH - A numerical measure of hydrogen ion activity, the neutral point being 7.0. All pH values below 7.0 are acid, and all above 7.0 are alkaline.

Phosphorus (available) - Inorganic phosphorus that is readily available for plant growth.

Phreatic Surface - The free surface of ground water at atmospheric pressure.

Physiographic Region (province) - Large-scale unit of land defined by its climate, geology, and geomorphic history, and therefore uniform in physiography.

Piezometer - An instrument for measuring pore water pressure within soil, rock, or concrete. The piezometric water surface is the water level in a piezometer.

Piping - The progressive development of internal erosion by seepage, appearing downstream as a hole or seam discharging water that contains soil particles. Water in the soil carries the fine soil particles away, and a series of eroded tubes or tunnels develop. These openings will grow progressively larger and can cause a dam failure.

Plunge Pool - A basin used to dissipate the energy of flowing water. Usually constructed to a design depth and shape. The pool may be protected from erosion by various lining materials.

PMP - Probable maximum precipitation event. The greatest theoretical depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location, based upon National Weather Service hydrometeorological reports.

Pore Pressure - The interstitial pressure of water within a mass of soil, rock, or concrete. Pore pressure is a result of the height of water above the point of measurement.

Porosity - The volume of pore space in soil or rock.

Principal Spillway - A dam spillway generally constructed of permanent material and designed to regulate and discharge water from the reservoir.

Pressure Relief Pipes - Pipes used to relieve uplift or pore pressure in a dam foundation or in the dam structure.

Professional Engineer – An individual who, because of special knowledge of the: 1) mathematical and physical sciences; and 2) principles and methods of engineering analysis and design; that are acquired by education and practical experience, is qualified to engage in the practice of engineering, as attested by the individual's registration as a professional engineer and license to practice engineering in Indiana.

Qualified Dam Safety Professional - See Dam Safety Professional.

Rainfall Intensity - The rate at which rain is falling at any given instant, usually expressed in inches per hour.

Rational Method - A means of computing storm drainage flow rates (Q) by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the drainage area.

Reach - The smallest subdivision of the drainage system, consisting of a uniform length of open channel. Also, a discrete portion of river, stream or creek. For modeling purposes, a reach is somewhat homogeneous in its physical characteristics.

Receiving Stream - The body of water into which runoff or effluent is discharged.

Recharge - Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Recurrence Interval - A statistical expression of the average time between floods equaling or exceeding a given magnitude.

Relief Well - See Drains.

Reservoir – Any impoundment or potential impoundment created by a dam. A natural or artificially created pond, lake or other space used for storage, regulation or control of water. May be either permanent or temporary. The term is also used in the hydrologic modeling of storage facilities.

Reservoir Area - The surface area of a reservoir when filled to controlled retention water level.

Reservoir Surface - The surface of a reservoir at any level.

Retention - The storage of stormwater to prevent it from leaving the development site. May be temporary or permanent.

Retention Facility - A facility designed to completely retain a specified amount of stormwater runoff without release except by means of evaporation, infiltration or pumping. The volumes are often referred to in units of acre-feet. Dams are retention facilities.

Revetment - Facing of stone or other material, either permanent or temporary, placed along the edge of a stream to stabilize the bank and protect it from the erosive action of the stream. Also see Riprap.

Rill - A small intermittent watercourse with steep sides, usually only a few inches deep.

Riprap - A layer of large stones, broken rock, boulders, or precast blocks placed in random fashion on the upstream slope of an embankment dam, on a reservoir shore, or on the sides of a channel as a protection against waves, ice action, and flowing water. Very large riprap is sometimes referred to as armoring. Revetment riprap is material graded such that: (1) no individual piece weighs more than 120 lbs; and (2) 90-100% will pass through a 12-inch sieve, 20-60% through a 6-inch sieve, and not more than 10% through a 1 1/2-inch sieve.

Riser - The inlet portions of a drop inlet spillway that extend vertically from the conduit to the water surface.

Rockfill Dam - See Embankment Dam.

Runoff - That portion of precipitation that flows from a drainage area on the land surface, in open channels, or in stormwater conveyance systems.

Sand - (1) Soil particles between 0.05 and 2.0 mm in diameter; (2) a soil textural class inclusive of all soils that are at least 70% sand and 15% or less clay.

Saturation - In soils, the point at which a soil or aquifer will no longer absorb any amount of water without losing an equal amount.

Scour(ing) - The clearing and digging action of flowing water, especially the downward erosion caused by discharge from a dam spillway, or stream water in washing away mud and silt from the stream bed and outside bank of a curved channel.

Scarp - The nearly vertical, exposed earth surface created at the upper edge of a slide or slough, or a beached area along the upstream slope.

Sediment - Solid material (both mineral and organic) that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface.

Sedimentation - The process that deposits soils, debris and other materials either on the ground surfaces or in bodies of water or watercourses.

Sediment Delivery Ratio - The fraction of the soil eroded from upland sources that actually reaches a stream channel or storage reservoir.

Sediment Discharge - The quantity of sediment, measured in dry weight or by volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Sediment Pool - The reservoir space allotted to the accumulation of sediment during the life of the structure.

Seepage - The interstitial movement of water that may take place through a dam, its foundation, or its abutments. The slow percolation (or oozing) of a fluid through a permeable material. A small amount of seepage will normally occur in any dam or embankment that retains water. The rate will depend on the relative permeability of the material in and under the structure, the depth of water behind the structure, and the length of the path the water must travel through or under the structure.

Seedbed - Soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Settling Basin - An enlargement in the channel of a stream to permit the settling of debris carried in suspension.

Silt - (1) Soil fraction consisting of particles between 0.002 and 0.05 mm in diameter; (2) a soil textural class indicating more than 80% silt.

Silt Fence - A fence constructed of wood or steel supports and either natural (e.g. burlap) or synthetic fabric stretched across area of non-concentrated flow during site development to trap and retain on-site sediment due to rainfall runoff.

Slide - The movement of a mass of earth and/or rock down a slope. In embankments and abutments, this involves the separation of a portion of the slope from the surrounding material.

Slope - Degree of deviation of a surface from the horizontal, measured as a numerical ratio or percent. Expressed as a ratio, the first number is commonly the horizontal distance (run) and the second is the vertical distance (rise) - e.g., 2:1. However, the preferred method for designation of slopes is to clearly identify the horizontal (H) and vertical (V) components – e.g., 2H:1V. Also note that according to international standards (Metric), the slopes are presented as the vertical or width component shown on the numerator--e.g., 1V:2H. Slope expressions in this handbook follow the common presentation of slopes - e.g., 2H:1V. Slopes can also be expressed in "percent" or “degrees.” Slopes given in percents are always expressed as (V/H) - e.g., a 2H:1V (1V:2H) slope is a 50% slope. The term gradient is also used.

Slope Protection - The protection of a slope against wave action or erosion.

Slough(ing) - The separation from the surrounding material and downhill movement of a small portion of the slope. Usually a slough refers to a shallow earth slide.

Sluiceway - See Low-Level Outlet.

Soil - The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. Also see alluvial soil, Clay, Cohesive soil, Loam, Permeability (soil), Sand, Silt, Soil Horizon, Soil Profile, Subsoil, Surface soil, Topsoil.

Soil Horizon - A horizontal layer of soil that, through processes of soil formation, has developed characteristics distinct from the layers above and below.

Soil Profile - A vertical section of the soil from the surface through all horizons.

Soil Structure -The relation of particles that impact to the whole soil a characteristic manner of breaking - e.g., crumb, block, platy, or columnar structure.

Soil Texture - The physical structure or character of soil determined by the relative proportions of the soil separates (sand, silt, and clay) of which it is composed.

Spalling - Breaking (or erosion) of small fragments from the surface of concrete masonry or stone under the action of weather or abrasive forces.

Specific Gravity - The ratio of (1) the weight in air of a given volume of soil solids at a stated temperature to (2) the weight in air of an equal volume of distilled water at a stated temperature.

Spillway (Spillway System) - A structure or structures that conveys flow through, around, or over the dam. A spillway system typically consists of the following: 1) A principle spillway. 2) An emergency spillway. 3) A drawdown mechanism.

Stilling Basin - A basin constructed to dissipate the energy of fast-flowing water, e.g., from a spillway or bottom outlet, and to protect the streambed from erosion.

Stoplogs - Wooden boards, timber, or steel beams or panels spanning horizontally between slots or grooves recessed in the sides of supporting piers placed on top of each other with their ends held in guides on each side of a channel or conduit providing a temporary closure versus a permanent bulkhead gate.

Storm Event – A storm event that can be categorized as having a specific frequency for a given duration. For example, a 10-yr. frequency, 24-hr duration storm event is a 24-hour storm that has a 10% probability of occurring in any one year.

Storm Frequency - The time interval between major storms of predetermined intensity and volumes of runoff - e.g., a 5-yr, 10-yr. or 20-yr storm.

Stormwater Runoff - The water derived from rains falling within a watershed or drainage area, flowing over the surface of the ground or collected in channels or conduits.

Storm Sewer - A sewer that carries stormwater, surface drainage, street wash, and other wash waters but excludes sewage and industrial wastes. Also called a storm drain.

Stream - See Intermittent Stream, Perennial stream, Receiving stream.

Streambanks - The usual boundaries (not the flood boundaries) of a stream channel. Right and left banks are named facing downstream.

Structural Joint - A joint constructed where movement of a part of a structure, due to temperature or moisture variations, settlement, or any other cause, would result in harmful displacement of adjoining structural components.

Subarea/Subbasin - Portion of a watershed divided into homogenous drainage units which can be modeled for purposes of determining runoff rates. The subareas/subbasins have distinct boundaries, as defined by the topography of the area.

Subsoil - The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below which roots do not normally grow.

Subsurface Drain - A pervious backfilled trench, usually containing stone and perforated pipe, for intercepting groundwater or seepage.

Subwatershed - A watershed subdivision of unspecified size that forms a convenient natural unit. See also Subarea.

Surface Runoff - See Runoff.

Surface Soil - The uppermost part of the soil ordinarily moved in tillage or its equivalent in an uncultivated soil. Frequently referred to as the plow layer. Surface soil is usually darker in color due to the presence of organic matter.

Suspended Solids - Solids either floating or suspended in water.

Swale - An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and may provide some groundwater recharge.

Tailwater - The water surface elevation at the downstream side of a hydraulic structure (i.e. culvert, bridge, weir, dam, etc.).

Time of Concentration (tc) - Is the travel time of a particle of water from the most hydraulically remote point in the contributing area to the point under study. This can be considered the sum of an overland flow time and times of travel in street gutters, storm sewers, drainage channels, and all other drainage ways.

Toe of Dam - The lowermost portion of the dam embankment where the embankment intersects the ground surface. Also referred to as "downstream toe" or "upstream toe."

Toe of Slope - The base or bottom of a slope at the point where the ground surface abruptly changes to a significantly flatter grade.

Top of Dam - The elevation of the uppermost surface of a dam excluding any parapet wall, railings, etc.

Topographic Map - Graphical portrayal of the topographic features of a land area, showing both the horizontal distances between the features and their elevations above a given datum. Elevations are typically shown with contour lines.

Topography - The representation of a portion of the earth's surface showing natural and man-made features of a give locality such as rivers, streams, ditches, lakes, roads, buildings and most importantly, variations in ground elevations for the terrain of the area.

Topsoil - (1) The dark-colored surface layer, or A horizon, of a soil; when present it ranges in depth from a fraction of an inch to 2-3 ft. (2) Equivalent to the plow layer of cultivated soils. (3) Commonly used to refer to the surface layer(s), enriched in organic matter and having textural and structural characteristics favorable for plant growth.

Trash Rack - A screen located at an intake to prevent the ingress of debris. A trash rack is typically a structure of metal or reinforced concrete bars located at the intake of a waterway, designed to prevent entrance of floating or submerged debris of a certain size and larger.

Turbidity - (1) Cloudiness of a liquid, caused by suspended solids. (2) A measure of the suspended solids in a liquid.

Underdrain - A small diameter perforated pipe that allows the bottom of an embankment, detention basin, channel or swale to drain.

Unified Soil Classification System (USCS) - A system of classifying soils that is based on their identification according to particle size, gradation, plasticity index, and liquid limit.

Uniform Flow - A state of steady flow when the mean velocity and cross-sectional area remain constant in all sections of a reach.

Uplift - The upward pressure in the pores of a material (interstitial pressure) or on the base of a structure.

Valve - A device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway so as to control or stop the flow.

Vegetative Stabilization - Protection of erodible or sediment producing areas with: permanent seeding (producing long-term vegetative cover), short-term seeding (producing temporary vegetative cover), or sodding (producing areas covered with a turf of perennial sod-forming grass).

Water Table - (1) The free surface of the groundwater. (2) That surface subject to atmospheric pressure under the ground, generally rising and failing with the season or from other conditions such as water withdrawal.

Watercourse - Any river, stream, creek, brook, branch, natural or man-made drainageway in or into which stormwater runoff or floodwaters flow either continuously or intermittently.

Watershed - The region drained by or contributing water to a specific point that could be along a stream, lake or other stormwater facilities. Watersheds are often broken down into subareas for the purpose of hydrologic modeling.

Watershed Area - All land and water within the confines of a drainage divide. See also Watershed.

Weep Holes - Openings left in retaining walls, aprons, linings, or foundations to permit drainage and reduce pressure.

Waterstop - A strip of metal, rubber, or other material used to prevent leakage through joints between adjacent sections of concrete.

Weir - A channel-spanning structure for measuring or regulating the flow of water. A type of spillway in which flow is constricted and caused to fall over a crest. Types of weirs include broad-crested weir, ogee weir, v-notch weir, sharp-crested weir, drowned weir, and submerged weir.

Weir Notch - The opening in a weir for the passage of water.

Wetlands - Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions and/or those wetland areas that are under the USACE jurisdiction.

APPENDIX B

SAMPLE INSPECTION CHECKLIST

Dam Safety Inspection Checklist

Complete All Portions of This Section (Pre-inspection)
Date of Inspection:____________________
Name of Dam:____________________File Number:____________________
EAP: (yes, no) OM&I: (yes, no)

Review Inventory - Highlight missing information (Pre -inspection)
Owner=s Name(s):____________________
Address:____________________
City:____________________State:____________________Zip (+4):____________________
Telephone (Home):____________________Telephone (Work):____________________
Contact Person:____________________Telephone:____________________
Designed By:____________________
Constructed By:____________________
Year Completed:____________________Plans Available (Yes, No) (location):____________________
Purpose of dam:____________________

Interview with Owner (at the site):
Owner/Representative present: (Yes, No) Name(s):____________________

Double check address, telephone #, purpose (check ->) G
How long have you owned dam - previous name/owner?____________________

EAP/OM&I: up-dated-(yes, no) & location:____________________
Operate lake drain (times per year, accessibility):____________________

Mowing (times per year):____________________
Prior problems (wet areas, erosion, slides): ____________________

Repair or modification (what & when): ____________________

Failure/Incident/Breach (max. pool):____________________

Downstream hazard status (recent changes):____________________

Do you know the in-depth details of the construction of your dam? (If yes - ask next three questions, if no - go to Field Information Section)
Core trench material and location:____________________
Volume of fill (earth or rock) in dam:____________________
Foundation (earth or rock) of dam:____________________

Field Information (while at site)
Pool Elevation (during inspection):____________________Time:____________________(a.m. p.m.)
Site Conditions(temp., weather, ground moisture):____________________

Inspection Party:____________________
Maximum Height:____________________(measured or inventory appears correct)
Normal Pool Surface Area:____________________(measured or inventory appears correct)

Required Action

None Monitor Maintenance Engineer

UPSTREAM SLOPE

Gradient: Horizontal:__________ Vertical:____________ (est, meas.)

☐ ***VEGETATION*** [no problem]

☐ Trees: Quantity: (<5, sparse, dense)______________ ☐ ☐ ☐ ☐
Diameter: (<6", 6-12", >12")______________
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes:______________

☐ Brush: Quantity: (sparse, dense) ______________ ☐ ☐ ☐ ☐
Location:(adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes:______________

☐ Ground Cover: Type: (grass, crown vetch) Other:______________ ☐ ☐ ☐ ☐
Quantity: (bare, sparse, adequate, dense)______________
Appearance: (too tall, too short, good)______________
Notes:______________

☐ ***SLOPE PROTECTION*** [no problem, could not inspect thoroughly]

☐ None ☐ ☐ ☐ ☐
☐ Riprap: Average Diameter: ______________ ☐ ☐ ☐ ☐
(adequate, sparse, displaced, weathered, vegetation) (bedding/fabric noted - yes, no)
Notes:______________

☐ Wave Berm: ☐ ☐ ☐ ☐
Vegetation: (adequate, bare, sparse, improper vegetation) ______________
Notes:______________

☐ Concrete Slabs: (cracked, settlement, undermined, voids, deteriorated, vegetation) ☐ ☐ ☐ ☐
Notes:______________

☐ Other:______________ ☐ ☐ ☐ ☐
Notes:______________

☐ ***EROSION*** [no problem, could not inspect thoroughly]

☐ Wave Erosion (Beaching): Scarp: Length: __________ Height: __________ ☐ ☐ ☐ ☐
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes:______________

☐ Runoff Erosion (Gullies): Quantity: ________ ☐ ☐ ☐ ☐
Depth: ________ Width: ________ Length: ________
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes/Causes:______________

☐ ***INSTABILITIES*** [no problem, could not inspect thoroughly]

☐ Slides: Transverse Length: __________ Longitudinal Length: __________ ☐ ☐ ☐ ☐
Scarp: Width: ________ Length: ________
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Crack: Width: __________ Depth: __________
Notes/Causes:______________

☐ Cracks: ☐ Transverse ☐ Longitudinal ☐ Other ☐ ☐ ☐ ☐
Quantity: ________ Length: ________ Width: ________ Depth: ________
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes/Causes:______________

None Monitor Maintenance Engineer

Required Action

Required Action

None Monitor Maintenance Engineer

☐ Cracks: ☐ Transverse ☐ Longitudinal ☐ Other ☐ ☐ ☐ ☐
Quantity: ________ Length: ____________ Width: ______________ Depth: ______________
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes/Causes: ______________

☐ Bulges ☐ Depressions ☐ Hummocky ☐ ☐ ☐ ☐
Size: ____________ Height: ____________ Depth: ________
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes/Causes: ______________

☐ Bulges ☐ Depressions ☐ Hummocky ☐ ☐ ☐ ☐
Size: ____________ Height: ____________ Depth: ________
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes/Causes: ______________

☐ ***OTHER*** [no problem, could not inspect thoroughly]

☐ Rodent Burrows: (few, numerous) ______________ ☐ ☐ ☐ ☐
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Notes: ______________

☐ Ruts: ☐ ☐ ☐ ☐
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______________
Depth: ____________ Width: ____________ Length: ______________
Notes/Causes: (truck/auto, motorcycle, ATV, animals, pedestrian): ______________

☐ Other: ______________ ☐ ☐ ☐ ☐
Notes: ______________

CREST

Length: ______________ Width: ______________ (est, meas.)

☐ ***VEGETATION*** [no problem]

☐ Trees: Quantity: (<5, sparse, dense) ☐ ☐ ☐ ☐
Diameter: (<6", 6-12", >12") ______________
Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______________
Notes: ______________

☐ Brush: Quantity: (sparse, dense) ______________ ☐ ☐ ☐ ☐
Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______________
Notes: ______________

☐ Ground Cover: Type: (grass, crown vetch) Other: ______________ ☐ ☐ ☐ ☐
Quantity: (bare, sparse, adequate, dense) ______________
Appearance: (too tall, too short, good) ______________
Notes: ______________

☐ ***EROSION*** [no problem, could not inspect thoroughly]

☐ Runoff Erosion (Gullies): Quantity: ________ Depth: ________ Width: ________ Length: ________ ☐ ☐ ☐ ☐
Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg)
Notes/Causes: ______________

None Monitor Maintenance Engineer

Required Action

Required Action

None Monitor Maintenance Engineer

☐ ***ALIGNMENT*** [no problem, could not inspect thoroughly]

☐ Vertical: ☐ Low Area: ☐ ☐ ☐ ☐

Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______

Elevation Difference: ______ Length: ______

Notes/Causes: ______

☐ ☐ ☐ ☐

☐ Horizontal:

Notes/Causes: ______

☐ ***WIDTH*** [no problem]

☐ Too Narrow

Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______ ☐ ☐ ☐ ☐

Notes/Causes: ______

☐ ***INSTABILITIES*** [no problem, could not inspect thoroughly]

☐ Cracks: ☐ Transverse ☐ Longitudinal ☐ Other ☐ ☐ ☐ ☐

Quantity: ______ Length: ______ Width: ______ Depth: ______

Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______

Notes/Causes:_ ______

☐ Cracks: ☐ Transverse ☐ Longitudinal ☐ Other ☐ ☐ ☐ ☐

Quantity: ______ Length: ______ Width: ______ Depth: ______

Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______

Notes/Causes:_ ______

☐ Bulges ☐ Depressions ☐ Hummocky ☐ ☐ ☐ ☐

Size: ______ Height: ______ Depth: ______

Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______

Notes/Causes: ______

☐ Bulges ☐ Depressions ☐ Hummocky ☐ ☐ ☐ ☐

Size: ______ Height: ______ Depth: ______

Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______

Notes/Causes: ______

☐ ***OTHER*** [no problem, could not inspect thoroughly]

☐ Rodent Burrows: (few, numerous) ______ ☐ ☐ ☐ ☐

Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______

Notes: ______

☐ Ruts: ☐ ☐ ☐ ☐

Location: (adj. to structure, entire crest, lt end, rt end, middle, see dwg) ______

Depth: ______ Width: ______ Length: ______

Notes/Causes: (truck/auto, motorcycle, ATV, animals, pedestrian): ______

☐ ☐ ☐ ☐

☐ Other: ______

Notes: ______

None Monitor Maintenance Engineer

Required Action

Required Action

None Monitor Maintenance Engineer

DOWNSTREAM SLOPE Gradient: Horizontal:__________ Vertical:______________(est, meas.)

☐ ***VEGETATION*** [no problem]

☐ Trees: Quantity: (<5, sparse, dense) ______ ☐ ☐ ☐ ☐
Diameter: (<6", 6-12", >12") ______
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______
Notes: ______

☐ Brush: Quantity: (sparse, dense) ______ ☐ ☐ ☐ ☐
Location:(adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______
Notes: ______

☐ Ground Cover: Type: (grass, crown vetch) Other: ______ ☐ ☐ ☐ ☐
Quantity: (bare, sparse, adequate, dense) ______
Appearance: (too tall, too short, good) ______
Notes: ______

☐ ***EROSION*** [no problem, could not inspect thoroughly]

☐ Runoff Erosion (Gullies): Quantity: ______ Depth: ______ Width: ______ Length: ______ ☐ ☐ ☐ ☐
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______
Notes/Causes: ______

☐ ***INSTABILITIES*** [no problem, could not inspect thoroughly]

☐ Slides: Transverse Length: ______ Longitudinal Length: ______ ☐ ☐ ☐ ☐
Scarp: Width: ______ Length: ______
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______
Crack: Width: ______ Depth: ______
Notes/Causes: ______

☐ Cracks: ☐ Transverse ☐ Longitudinal ☐ Other ☐ ☐ ☐ ☐
Quantity: ______ Length: ______ Width: ______ Depth: ______
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______
Notes/Causes: ______

☐ Cracks: ☐ Transverse ☐ Longitudinal ☐ Other ☐ ☐ ☐ ☐
Quantity: ______ Length: ______ Width: ______ Depth: ______
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______
Notes/Causes: ______

☐ Bulges ☐ Depressions ☐ Hummocky ☐ ☐ ☐ ☐
Size: ______ Height: ______ Depth: ______
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______
Notes/Causes: ______

☐ Bulges ☐ Depressions ☐ Hummocky ☐ ☐ ☐ ☐
Size: ______ Height: ______ Depth: ______
Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg) ______
Notes/Causes: ______

None Monitor Maintenance Engineer

Required Action

Required Action
None Monitor Maintenance Engineer

☐ ***OTHER*** [no problem, could not inspect thoroughly]

☐ Rodent Burrows: (few, numerous) ☐ ☐ ☐ ☐

Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg)

Notes:

☐ Ruts: ☐ ☐ ☐ ☐

Location: (adj. to structure, entire slope, lt end, rt end, middle, see dwg)

Depth: Width: Length:

Notes/Causes: (truck/auto, motorcycle, ATV, animals, pedestrian):

☐ Other: ☐ ☐ ☐ ☐

Notes:

☐ ***SEEPAGE*** [no problem, could not inspect thoroughly]

☐ Wet Area ☐ Flow ☐ Boil ☐ Sinkhole ☐ ☐ ☐ ☐

Flow Rate Size:

Location:

☐ Aquatic Vegetation ☐ None

☐ Rust Colored Deposits ☐ None

☐ Sediment in Flow ☐ None

☐ Other:

Notes/Causes:

☐ Wet Area ☐ Flow ☐ Boil ☐ Sinkhole ☐ ☐ ☐ ☐

Flow Rate Size:

Location:

☐ Aquatic Vegetation ☐ None

☐ Rust Colored Deposits ☐ None

☐ Sediment in Flow ☐ None

☐ Other:

Notes/Causes:

☐ ***EMBANKMENT DRAINS*** [none, none found, no problem, could not inspect thoroughly]

Type: ☐ Toe Drain ☐ Relief Wells ☐ Other: ☐ ☐ ☐ ☐

Flow Rate: Size: Number:

Location:

Notes:

☐ ***MONITORING INSTRUMENTATION*** [none, none found, no problem, could not inspect thoroughly]

☐ None Found ☐ Piezometers ☐ Weirs/Flumes ☐ Other ☐ ☐ ☐ ☐

☐ Periodic Inspections by:

Notes:

None Monitor Maintenance Engineer
Required Action

Required Action

None Monitor Maintenance Engineer

PRINCIPAL SPILLWAY

☐ ***GENERAL INLET*** [no problem, could not inspect thoroughly]

☐ Anti-Vortex Plate [None] Dimensions:________________ (adequate, too small,) ☐ ☐ ☐ ☐

Type: (steel, concrete, aluminum, stainless steel, corrugated metal wood, other):________________

Deterioration: (missing sections, rusted, collapsed)________________

Notes:________________

☐ Flash Boards [None] ☐ ☐ ☐ ☐

Type: (metal, wood):________________

Deterioration:________________

Notes:________________

☐ Trashrack [None] Opening Size:________ (adequate, too small, too large) ☐ ☐ ☐ ☐

Type: (metal bars, fence, screen, concrete, baffle, other):________________

Deterioration: (broken bars, missing sections, rusted, collapsed)________________

Notes:________________

☐ ***INLET OBSTRUCTION*** [no problem, could not inspect thoroughly]

☐ Debris: (leaves, trash, logs, branches, ice)________________ ☐ ☐ ☐ ☐

☐ Trees: Quantity: (<5, sparse, dense)________________ ☐ ☐ ☐ ☐

Diameter: (<6", 6-12", >12")________________

Location: (entire inlet, lt side, rt side, middle, see dwg)________________

Notes:________________

☐ Brush: Quantity: (sparse, dense)________________ ☐ ☐ ☐ ☐

Location: (entire inlet, lt side, rt side, middle, see dwg)________________

Notes:________________

☐ Other:(beaver activity, trashrack opening too small, partially/completely blocked, i.e.)________________ ☐ ☐ ☐ ☐

Notes:________________

☐ ***INLET MATERIALS*** [no problem, could not inspect thoroughly]

☐ Metal

(loss of coating/paint, surface rust, corrosion (pitting, scaling), rusted out, pipe deformation)________________ ☐ ☐ ☐ ☐

Dimensions:________________

Location:________________

Notes/Causes:________________

☐ Concrete

(bug holes, hairline crack, efflorescence)________________ ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks)________________ ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other)________________ ☐ ☐ ☐ ☐

Dimensions/Location:________________

Notes/Causes:________________

(bug holes, hairline crack, efflorescence)________________ ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks)________________ ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other)________________ ☐ ☐ ☐ ☐

Dimensions/Location:________________

Notes/Causes:________________

☐ Plastic ☐ ☐ ☐ ☐

(deterioration, cracking, deformation)________________

Dimensions:________________

Location:________________

Notes/Causes:________________

None Monitor Maintenance Engineer

Required Action

Required Action

None Monitor Maintenance Engineer

☐ Earthen

☐ Ground Cover: Type: (grass, crown vetch) Other: ☐ ☐ ☐ ☐

Quantity: (bare, sparse, adequate, dense)

Appearance: (too tall, too short, good)

Notes:

☐ Erosion: (wave, surface runoff) ☐ ☐ ☐ ☐

Description (height/depth/length/etc):

Notes:

☐ Ruts: ☐ ☐ ☐ ☐

Location: (entire inlet, lt side, rt side, middle, see dwg)

Depth: Width: Length:

Notes/Causes: (truck/auto, motorcycle, ATV, animals, pedestrian):

☐ Riprap: Average Diameter: ☐ ☐ ☐ ☐

(adequate, sparse, displaced, weathered, vegetation) (bedding/fabric noted - yes, no)

Notes:

☐ Rock-Cut (weathered, erosion) ☐ ☐ ☐ ☐

Description:

Notes:

☐ Other: ☐ ☐ ☐ ☐

☐ ***OTHER INLET PROBLEMS*** [no problem, could not inspect thoroughly]

☐ Mis-Alignment:(pipe, chute, sidewall, headwall) ☐ Pipe Deformation ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Separated Joint ☐ Loss of Joint Material ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Undermining: ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Other: ☐ ☐ ☐ ☐

☐ ***OPEN CHANNEL CONTROL SECTION*** [no problem, could not inspect] **Width** (est., ms.) **Brdth** (est., ms.) ☐ ☐ ☐ ☐

Notes:

☐ ***OUTLET OBSTRUCTION*** [no problem, could not inspect thoroughly]

☐ Debris: (leaves, trash, logs, branches, ice) ☐ ☐ ☐ ☐

☐ Trees: Quantity: (<5, sparse, dense) ☐ ☐ ☐ ☐

Diameter: (<6", 6-12", >12")

Location: (entire outlet, lt side, rt side, middle, see dwg)

Notes:

☐ Brush: Quantity: (sparse, dense) ☐ ☐ ☐ ☐

Location:(entire outlet, lt side, rt side, middle, see dwg)

Notes:

Required Action

☐ Other:(beaver activity, partially/completely blocked, i.e.) ☐ ☐ ☐ ☐

Notes:

None Monitor Maintenance Engineer

Required Action

None Monitor Maintenance Engineer

☐ ***OUTLET MATERIALS*** [no problem, could not inspect thoroughly]

☐ Metal (loss of coating/paint, surface rust, corrosion (pitting, scaling), rusted out, pipe deformation) ☐ ☐ ☐ ☐
Dimensions:
Location:
Notes/Causes:

☐ Concrete
(bug holes, hairline crack, efflorescence) ☐ ☐ ☐ ☐
(spalling, popouts, honeycombing, scaling, craze/map cracks) ☐ ☐ ☐ ☐
(isolated crack, exposed rebar, disintegration, other) ☐ ☐ ☐ ☐
Dimensions/Location:
Notes/Causes:

(bug holes, hairline crack, efflorescence) ☐ ☐ ☐ ☐
(spalling, popouts, honeycombing, scaling, craze/map cracks) ☐ ☐ ☐ ☐
(isolated crack, exposed rebar, disintegration, other) ☐ ☐ ☐ ☐
Dimensions/Location:
Notes/Causes:

☐ Plastic (deterioration, cracking, deformation) ☐ ☐ ☐ ☐
Dimensions:
Location:
Notes/Causes:

☐ Earthen
☐ Ground Cover: Type: (grass, crown vetch) Other: ☐ ☐ ☐ ☐
Quantity: (bare, sparse, adequate, dense)
Appearance: (too tall, too short, good)
Notes:

☐ Erosion: (other, surface runoff) ☐ ☐ ☐ ☐
Description (width/depth/length/etc):
Notes:

☐ Ruts: ☐ ☐ ☐ ☐
Location: (entire inlet, lt side, rt side, middle, see dwg)
Depth: Width: Length:
Notes/Causes: (truck/auto, motorcycle, ATV, animals, pedestrian):

☐ Riprap: Average Diameter: ☐ ☐ ☐ ☐
(adequate, sparse, displaced, weathered, vegetation) (bedding/fabric noted - yes, no)
Notes:

☐ Rock-Cut (weathered, erosion)
Description/Notes: ☐ ☐ ☐ ☐

☐ Other: ☐ ☐ ☐ ☐

☐ ***OTHER OUTLET PROBLEMS*** [no problem, could not inspect thoroughly]

☐ Mis-Alignment:(pipe, chute, sidewall, headwall) ☐ Pipe Deformation ☐ ☐ ☐ ☐
Location/Description:
Notes/Causes:

None Monitor Maintenance Engineer

☐ Separated Joint ☐ Loss of Joint Material ☐ ☐ ☐ ☐
Location/Description:
Notes/Causes:

☐ Undermining: ☐ ☐ ☐ ☐
Location/Description:
Notes/Causes:

☐ Other: ☐ ☐ ☐ ☐

Required Action

Required Action

None Monitor Maintenance Engineer

OUTLET EROSION CONTROL STRUCTURE (Stilling Basins)

☐ None ☐ ☐ ☐ ☐

☐ (endwall/headwall, plunge pool, impact basin, flip bucket, USBR, baffled chute, rock lined channel) ☐ ☐ ☐ ☐

Notes:

Components (baffle blocks, chute blocks, endsill)

☐ ***MATERIAL*** [no problem, could not inspect thoroughly]

☐ Riprap: Average Diameter: ☐ ☐ ☐ ☐

(adequate, sparse, displaced, weathered, vegetation) (bedding/fabric noted - yes, no)

Notes:

☐ Concrete

(bug holes, hairline crack, efflorescence) ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks) ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other) ☐ ☐ ☐ ☐

Dimensions/Location:

Notes/Causes:

(bug holes, hairline crack, efflorescence) ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks) ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other) ☐ ☐ ☐ ☐

Dimensions/Location:

Notes/Causes:

☐ ***OTHER*** [no problem, could not inspect thoroughly] ☐ ☐ ☐ ☐

☐ Mis-Alignment:(sidewall, headwall, entire struct.)

Location:

Description:

Notes/Causes:

☐ Separated Joint ☐ Loss of Joint Material ☐ ☐ ☐ ☐

Location:

Description:

Notes/Causes:

☐ Undermining: ☐ ☐ ☐ ☐

Location:

Description:

Notes/Causes:

☐ Other: ☐ ☐ ☐ ☐

☐ ***DRAINS*** [none, none found, no problem, could not inspect thoroughly] (See ***SEEPAGE*** Section for Toe Drains & Relief Wells)

Type: ☐ Weep Holes ☐ Relief Drains ☐ Other: ☐ ☐ ☐ ☐

Flow Rate: Size: Number:

Location:

Notes:

Type: ☐ Weep Holes ☐ Relief Drains ☐ Other: ☐ ☐ ☐ ☐

Flow Rate: Size: Number:

Location:

Notes:

None Monitor Maintenance Engineer

Required Action

Required Action

None Monitor Maint. Engineer

EMERGENCY SPILLWAY

☐ None Found ☐ ☐ ☐ ☐

☐ ***GENERAL INLET*** [no problem, could not inspect thoroughly]

☐ Anti-Vortex Plate [None] Dimensions:______ (adequate, too small,) ☐ ☐ ☐ ☐

Type: (steel, concrete, aluminum, stainless steel, corrugated metal wood, other):______

Deterioration: (missing sections, rusted, collapsed)______

Notes:______

☐ Flash Boards [None] ☐ ☐ ☐ ☐

Type: (metal, wood):______

Deterioration:______

Notes:______

☐ Trashrack [None] Opening Size:______ (adequate, too small, too large) ☐ ☐ ☐ ☐

Type: (metal bars, fence, screen, concrete, baffle, other):______

Deterioration: (broken bars, missing sections, rusted, collapsed)______

Notes:______

☐ ***INLET OBSTRUCTION*** [no problem, could not inspect thoroughly]

☐ Debris: (leaves, trash, logs, branches, ice)______ ☐ ☐ ☐ ☐

☐ Trees: Quantity: (<5, sparse, dense)______ ☐ ☐ ☐ ☐

Diameter: (<6", 6-12", >12")______

Location: (entire inlet, lt side, rt side, middle, see dwg)______

Notes:______

☐ Brush: Quantity: (sparse, dense)______ ☐ ☐ ☐ ☐

Location: (entire inlet, lt side, rt side, middle, see dwg)______

Notes:______

☐ Other:(beaver activity, trashrack opening too small, partially/completely blocked, i.e.)______ ☐ ☐ ☐ ☐

Notes:______

☐ ***INLET MATERIALS*** [no problem, could not inspect thoroughly]

☐ Metal

(loss of coating/paint, surface rust, corrosion (pitting, scaling), rusted out, pipe deformation)______ ☐ ☐ ☐ ☐

Dimensions/Location:______

Notes/Causes:______

☐ Concrete

(bug holes, hairline crack, efflorescence)______ ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks)______ ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other)______ ☐ ☐ ☐ ☐

Dimensions/Location:______

Notes/Causes:______

(bug holes, hairline crack, efflorescence)______ ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks)______ ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other)______ ☐ ☐ ☐ ☐

Dimensions/Location:______

Notes/Causes:______

☐ Plastic

(deterioration, cracking, deformation)______ ☐ ☐ ☐ ☐

Dimensions/Location:______

Notes/Causes:______

None Monitor Maintenance Engineer

Required Action

Required Action

None | Monitor | Maintenance | Engineer

☐ Earthen

☐ Ground Cover: Type: (grass, crown vetch) Other: ☐ ☐ ☐ ☐

Quantity: (bare, sparse, adequate, dense)

Appearance: (too tall, too short, good)

Notes:

☐ Erosion: (wave, surface runoff) ☐ ☐ ☐ ☐

Description (height/depth/length/etc):

Notes:

☐ Ruts: ☐ ☐ ☐ ☐

Location: (entire inlet, lt side, rt side, middle, see dwg)

Depth: Width: Length:

Notes/Causes: (truck/auto, motorcycle, ATV, animals, pedestrian):

☐ Riprap: Average Diameter: ☐ ☐ ☐ ☐

(adequate, sparse, displaced, weathered, vegetation) (bedding/fabric noted - yes, no)

Notes:

☐ Rock-Cut (weathered, erosion) ☐ ☐ ☐ ☐

Description:

Notes:

☐ Other: ☐ ☐ ☐ ☐

☐ ***OTHER INLET PROBLEMS*** [no problem, could not inspect thoroughly]

☐ Mis-Alignment:(channel, chute, sidewall, headwall) ☐ Pipe Deformation ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Separated Joint ☐ Loss of Joint Material ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Undermining: ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Other: ☐ ☐ ☐ ☐

☐ ***OPEN CHANNEL CONTROL SECTION*** [no problem, could not inspect] **Width** (est., ms.) **Brdth** (est., ms.) ☐ ☐ ☐ ☐

Notes:

☐ ***OUTLET OBSTRUCTION*** [no problem, could not inspect thoroughly]

☐ Debris: (leaves, trash, logs, branches, ice) ☐ ☐ ☐ ☐

☐ Trees: Quantity: (<5, sparse, dense) ☐ ☐ ☐ ☐

Diameter: (<6", 6-12", >12")

Location: (entire outlet, lt side, rt side, middle, see dwg)

Notes:

☐ Brush: Quantity: (sparse, dense) ☐ ☐ ☐ ☐

Location:(entire outlet, lt side, rt side, middle, see dwg)

Notes:

Required Action

☐ Other:(beaver activity, partially/completely blocked, i.e.) ☐ ☐ ☐ ☐

Notes:

None | Monitor | Maintenance | Engineer

Required Action

None Monitor Maint. Engineer

☐ ***OUTLET MATERIALS*** [no problem, could not inspect thoroughly]

☐ Metal (loss of coating/paint, surface rust, corrosion (pitting, scaling), rusted out, pipe deformation) ☐ ☐ ☐ ☐

Dimensions:

Location:

Notes/Causes:

☐ Concrete (bug holes, hairline crack, efflorescence) ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks) ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other) ☐ ☐ ☐ ☐

Dimensions/Location:

Notes/Causes:

(bug holes, hairline crack, efflorescence) ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks) ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other) ☐ ☐ ☐ ☐

Dimensions/Location:

Notes/Causes:

☐ Plastic (deterioration, cracking, deformation) ☐ ☐ ☐ ☐

Dimensions:

Location:

Notes/Causes:

☐ Earthen

☐ Ground Cover: Type: (grass, crown vetch) Other: ☐ ☐ ☐ ☐

Quantity: (bare, sparse, adequate, dense)

Appearance: (too tall, too short, good)

Notes:

☐ Erosion: (other, surface runoff) ☐ ☐ ☐ ☐

Description (width/depth/length/etc):

Notes:

☐ Ruts:

Location: (entire inlet, lt side, rt side, middle, see dwg) ☐ ☐ ☐ ☐

Depth: Width: Length:

Notes/Causes: (truck/auto, motorcycle, ATV, animals, pedestrian):

☐ Riprap: Average Diameter:

(adequate, sparse, displaced, weathered, vegetation) (bedding/fabric noted - yes, no) ☐ ☐ ☐ ☐

Notes:

☐ Rock-Cut (weathered, erosion)

Description: ☐ ☐ ☐ ☐

Notes:

☐ Other: ☐ ☐ ☐ ☐

☐ ***OTHER OUTLET PROBLEMS*** [no problem, could not inspect thoroughly]

☐ Mis-Alignment:(channel, chute, sidewall, headwall) ☐ Pipe Deformation ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

None Monitor Maintenance Engineer

☐ Separated Joint ☐ Loss of Joint Material ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Undermining: ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Other: ☐ ☐ ☐ ☐

Required Action

Required Action

None Monitor Maint. Engineer

OUTLET EROSION CONTROL STRUCTURE (Stilling Basins) ☐ ☐ ☐ ☐

☐ None

☐ (endwall/headwall, plunge pool, impact basin, flip bucket, USBR, baffled chute, rock lined channel) ☐ ☐ ☐ ☐

Notes:____

Components (baffle blocks, chute blocks, endsill)____________________

☐ ***MATERIAL*** [no problem, could not inspect thoroughly]

☐ Riprap: Average Diameter: ________________ ☐ ☐ ☐ ☐

(adequate, sparse, displaced, weathered, vegetation) (bedding/fabric noted - yes, no)

Notes:____

☐ Concrete

(bug holes, hairline crack, efflorescence) ________________ ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks)__________ ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other)__________ ☐ ☐ ☐ ☐

Dimensions/Location:______________________________

Notes/Causes:__________________________________

(bug holes, hairline crack, efflorescence) ________________ ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks)__________ ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other)__________ ☐ ☐ ☐ ☐

Dimensions/Location:______________________________

Notes/Causes:__________________________________

☐ ***OTHER*** [no problem, could not inspect thoroughly] ☐ ☐ ☐ ☐

☐ Mis-Alignment:(sidewall, headwall)____________________

Location:______________________________________

Description:___________________________________

Notes/Causes:__________________________________

☐ Separated Joint ☐ Loss of Joint Material ☐ ☐ ☐ ☐

Location:______________________________________

Description:___________________________________

Notes/Causes:__________________________________

☐ Undermining: ☐ ☐ ☐ ☐

Location:______________________________________

Description:___________________________________

Notes/Causes:__________________________________

☐ Other:____ ☐ ☐ ☐ ☐

☐ ***DRAINS*** [none, none found, no problem, could not inspect thoroughly] (See ***SEEPAGE*** Section for Toe Drains & Relief Wells)

Type: ☐ Weep Holes ☐ Relief Drains ☐ Other:________ ☐ ☐ ☐ ☐

Flow Rate:__________ Size:__________ Number:__________

Location:______________________________________

Notes:____

Type: ☐ Weep Holes ☐ Relief Drains ☐ Other:________ ☐ ☐ ☐ ☐

Flow Rate:__________ Size:__________ Number:__________

Location:______________________________________

Notes:____

None Monitor Maintenance Engineer

Required Action

Required Action

None Monitor Maint. Engineer

LAKE DRAIN

☐ ***GENERAL***

☐ None Found ☐ Does not have one ☐ ☐ ☐ ☐

☐ Type of Lake Drain (isolated control/intake tower, valve vault w/ outlet conduit, valve in riser/drop inlet, siphon) ☐ ☐ ☐ ☐

Notes:

☐ Operated During Inspection (yes, no) ☐ ☐ ☐ ☐

Notes:

☐ ***ACCESS TO VALVE/SLUICE GATE*** [no problem, could not inspect thoroughly] ☐ ☐ ☐ ☐

☐ Type (not accessible, from shore, boat, walkway, other)

Notes:

☐ Walkway/Platform:

☐ Concrete Deterioration ☐ Cracks (platform, piers, end supports, railing) ☐ ☐ ☐ ☐

Location:

Notes:

☐ Wood Deterioration ☐ ☐ ☐ ☐

Notes:

☐ Metal Deterioration ☐ ☐ ☐ ☐

(minor, moderate, extensive, other)

Notes:

☐ ***LAKE DRAIN COMPONENTS*** [no problem, could not inspect thoroughly]

☐ Concrete Structure ☐ ☐ ☐ ☐

Location:

Description: (deterioration, misalignment, cracks):

Notes/Causes:

☐ Valve Control (Operating Device)

☐ No Operating Device ☐ No Stem ☐ Bent/Broken Stem ☐ Other ☐ ☐ ☐ ☐

Notes/Operability:

☐ Valve / Sluice Gate

☐ Metal Deterioration: (surface rust, minor, moderate, extensive, other) ☐ ☐ ☐ ☐

Location:

Flow Rate:

Notes/Causes:

☐ Misalignment ☐ ☐ ☐ ☐

Notes/Causes:

☐ Leakage - Flow Rate: ☐ ☐ ☐ ☐

Notes/Causes:

☐ Valve / Sluice Gate

☐ Metal Deterioration: (surface rust, minor, moderate, extensive, other) ☐ ☐ ☐ ☐

Location:

Flow Rate:

Notes/Causes:

☐ Misalignment - Notes/Causes: ☐ ☐ ☐ ☐

Required Action

☐ Leakage - Flow Rate: ☐ ☐ ☐ ☐

Notes/Causes:

None Monitor Maintenance Engineer

Required Action

None | Monitor | Maintenance | Engineer

☐ Outlet Conduit

☐ Metal:(loss of coating/paint, surface rust, corrosion (pitting, scaling), rusted out) ☐ ☐ ☐ ☐

Location:

Notes/Causes:

☐ Concrete (bug holes, hairline crack, efflorescence) ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks) ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other) ☐ ☐ ☐ ☐

Dimensions/Location:

Notes/Causes:

☐ Plastic:(deterioration, cracking) ☐ ☐ ☐ ☐

Location:

Notes/Causes:

☐ Conduit Deformation ☐ Mis-Alignment: ☐ ☐ ☐ ☐

Location:

Notes/Causes:

☐ Separated Joint ☐ Loss of Joint Material ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Undermining: ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Vegetation (trees, brush) ☐ ☐ ☐ ☐

Notes:

☐ Other: ☐ ☐ ☐ ☐

Notes:

☐ Energy Dissipator

☐ Type (endwall, plunge pool, impact basin, stilling basin, rock-lined channel, none) ☐ ☐ ☐ ☐

Notes:

☐ Riprap: Average Diameter: ☐ ☐ ☐ ☐

(adequate, sparse, displaced, weathered, vegetation) (bedding/fabric noted - yes, no))

Notes:

☐ Concrete (bug holes, hairline crack, efflorescence) ☐ ☐ ☐ ☐

(spalling, popouts, honeycombing, scaling, craze/map cracks) ☐ ☐ ☐ ☐

(isolated crack, exposed rebar, disintegration, other) ☐ ☐ ☐ ☐

Dimensions/Location:

Notes/Causes:

☐ Mis-Alignment: ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Separated Joint ☐ Loss of Joint Material ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

☐ Undermining: ☐ ☐ ☐ ☐

Location/Description:

Notes/Causes:

Required Action

☐ Other: ☐ ☐ ☐ ☐

Notes:

None | Monitor | Maintenance | Engineer

APPENDIX C

SUGGESTED DAM INSPECTION REPORT

APPENDIX C

SUGGESTED DAM INSPECTION REPORT

TO OPEN A COPY OF THE SUGGESTED
DAM INSPECTION REPORT,
PLEASE CLICK HERE.

APPENDIX D

SKETCH OF DAM EMBANKMENT

Note: Inspector should indicate location and configuration of spillways on the plan.

Name of Dam	Inspector	Date

APPENDIX E

SUGGESTED OUTLINE OF INSPECTION REPORT

SUGGESTED OUTLINE OF INSPECTION REPORT

Title Sheet

- Name of dam
- State Inventory Identification Number
- County where dam is located
- River or stream where dam is located
- Owner and operator name, address, and telephone number
- Date of inspection
- Name, address, registration No., and signature of licensed professional engineer in charge of inspection report

Table of Contents

1.0 Executive Summary

- Name of dam
- Owner of dam
- Location of dam
- Size of dam (embankment, spillway, etc)
- Hazard classification
- Date of inspection
- Inspection team
- Conclusions
- Recommendations

2.0 Background Information

- Ownership and ownership changes
- Availability of design and/or construction plans
- Construction completion date
- Name of construction firm
- Past modifications
- Operational records and/or problems
- Incidents and/or failures
- Historic flood events

3.0 Project Information

- Location of dam with map
- Purpose of dam
- General site conditions
- Geologic conditions/setting
    - Regional geology
    - Site geology
        - general

- dam
- foundation and abutments (i.e., geologic description)
- treatment (e.g., excavation, grouting, etc.)
- evaluation

○ Landslide potential
- abutments
- reservoir rim

○ Seismicity
- general
- seismic zone and potential
- liquefaction potential

- Description of dam with pertinent data
- Description of spillway system with pertinent data
- Description of outlet works with pertinent data
- Description of other principal features with pertinent data
- Availability of design, geotechnical, maintenance, and construction plans
- Availability of repair and alteration plans
- Reference to past inspection reports and pertinent results

4.0 File Review (list all data reviewed from files and other sources)

5.0 Dam Safety Inspection (describe the results of the visual field inspection for each of the dam and spillway features)

5.1 Operational Status during Field Inspection
- weather conditions immediately preceding and during the inspection
- reservoir water surface elevation (relative to spillway)
- release rate from spillway (approximate depth of flow or rate)
- operational status of drawdown works

5.2 Upstream Slope and Shoreline
5.3 Crest
5.4 Downstream Slope
5.5 Spillway System
5.6 Outlet Works
5.7 Toe Drain (or other seepage control facilities)
5.8 Seepage
5.9 Watershed Features (note significant changes)
5.10 Downstream Area (note changes in hazards from previous inspection)
5.11 Suggested Dam Inspection Report
5.12 Photographs (inspection features and deficiencies, including downstream channel and areas)

<u>Note:</u> Consider static and dynamic stability, freeboard, drainage control, riprap, settlement, slumps, cracks, structural performance, major vegetation, erosion, etc. Discuss what data were (or were not) available for review and any design or construction methods used which differ from current techniques. State any design or construction deficiencies (e.g., no stability analysis performed, lack of

known material properties, no compaction of embankment materials, etc.). Also, state the existing conditions.

6.0 Structural Stability

- Summary of previous available information
  - geotechnical design data
  - seismic data/considerations
  - seepage analysis
  - slope stability analysis
  - previous evaluations
- Visual assessment of dam stability (based on available data)
- Results of evaluations performed as part of the inspection process

Note: Consider static and dynamic stability, freeboard, drainage control, riprap, settlement, slumps, cracks, structural performance, major vegetation, erosion, etc. Discuss what data were (or were not) available for review and any design or construction methods used which differ from current techniques. State any design or construction deficiencies (e.g., no stability analysis performed, lack of known material properties, no compaction of embankment materials, etc.). Also, state the existing conditions.

7.0 Hydrology/Hydraulics

- Summary of previous available information
  - hydrologic/hydraulic design data
  - drainage area
  - changes in watershed
  - floods of record
  - previous evaluations
- Visual assessment of adequacy of spillway system (based on available data)
- Results of evaluations performed as part of the inspection process

Note: Discuss the adequacy of the spillway for the current IDF (inflow design flood) or PMF (probable maximum flood). Consider capacity relative to floods, structural adequacy, hydraulic adequacy, operation, inlet conditions, channel or conduit conditions, stilling basin and/or outlet channel adequacy, etc.

8.0 Operation and Maintenance (O&M)

- Assessment of operating equipment and procedures
- Evaluation of current maintenance plan
- Recommended changes to O&M Plan
- Location of dam with map

9.0 Emergency Preparedness and Security

- hazard classification
- access to site
- communications
- warning system
- auxiliary power
- remote operation
- security of site
- reservoir evacuation potential
- operating instructions

10.0 Conclusions

10.1 Overall Evaluation (of structures condition, spillway capacity, operational adequacy, and structural integrity based on current inspection, past performance, documentation, and recent analyses; include an assessment of the adequacy of current hazard classification)

10.2 Risk of Failure (determination of potential for failure considering existing conditions and deficiencies)

- Objective evaluation of the risk of dam failure based on the inspection results, considering each dam component and the potential causes of failure (as described below)
- Risk of dam component failure (embankment upstream slope, crest, and downstream slope; spillway system; outlet works; outlet channel; dam abutments; dam foundation)
- Risk of uncontrolled breach failure (consider: structural factors, including deficiencies observed such as vegetation, seepage, sloughing, cracking, erosion, etc; Natural factors, including storms, earthquakes, tornados, etc; human factors, including vandalism and terrorism); operating factors, including water level management, maintenance procedures, flood control measures, water level controls, etc)

11.0 Recommendations

List of all recommendations. Recommendations should be written concisely, and they should focus on action to be taken. For convenience of reporting and tabulation, each recommendation should be numbered.

- Recommended maintenance, repairs, and alterations to the structure to eliminate deficiencies
- Recommended schedule for repairs and upgrades
- Recommendations fro additional studies and investigations, including schedule

12.0 Appendices (include as applicable)

- Engineering plans of the dam (if available)
- Dam sketch(es), including plan view and sections of pertinent features (submit once at first inspection; submit supplemental sketches to depict changes for subsequent inspections)
- Geotechnical Report
- Hydrologic and Hydraulic Calculations
- Stability Calculations
- Other Supporting Documentation

Note: If engineering plans, reports, analyses, or sketches have been submitted in a previous inspection report and if there have been no changes to the dam, it is not necessary to submit duplicate information in subsequent reports.

APPENDIX F

REFERENCES

REFERENCES
(Used throughout the manual)

- Arkansas Soil and Water Conservation Commission
  Inspection and Maintenance Manual for Arkansas Dam Owners, 2002
  101 East Capitol, Suite 350
  Little Rock, Arkansas 72201

- Association of State Dam Safety Officials
  Compendium of State Dam safety Inspection Forms, 1997
  450 Old East Vine Street
  Lexington, Kentucky 40507

- Colorado Division of Water Resources, State Engineer's Office
  Dam Safety Manual, 2002
  1313 Sherman Street
  Denver, Colorado 80203

- Department of the Army, U.S. Army Corps of Engineers
  Instrumentation for Concrete Structures, EM 1110-2-4300, 1987
  Washington, D.C. 20314-1000

- Department of the Army, U.S. Army Corps of Engineers
  Evaluation and Repair of Concrete Structures, EM 1110-2-2002, 1995
  Washington, D.C. 20314-1000

- Department of the Army, U.S. Army Corps of Engineers
  Seepage Analysis and Control for Dams, EM 1110-2-1901, 1993
  Washington, D.C. 20314-1000

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  Seepage Analysis and Control for Dams, EM 1110-2-1901, 1993
  Washington, D.C. 20314-1000

- Department of the Army, U.S. Army Corps of Engineers
  Instrumentation of Embankment Dams and Levees, EM 1110-2-1908, 1995
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  Earth and Rock-fill Dams - General Design& Construction Considerations, EM 1110-2-2300, 1994
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- Federal Emergency Management Agency
  Technical Manual: Conduits through Embankment Dams, 2005
  500 C Street SW
  Washington, D.C. 20472

- Georgia Department of Natural Resources, Environmental Protection Division
  - Operation, Maintenance and Inspection Procedures for Earthfill Dams
  - Engineering Guidelines, 1998
  4244 International Parkway, Suite 110
  Atlanta, Georgia 30354

- Illinois Department of Natural Resources, Office of Water Resources
  Guidelines and Forms for Inspection of Illinois Dams, 1999
  Springfield, Illinois, 62702

- Indiana Department of Natural Resources, Division of Soil Conservation
  Indiana Handbook for Erosion Control in Developing Areas, 1992
  402 West Washington Street, Room W265
  Indianapolis, Indiana 46204-2748

- Indiana Department of Natural Resources, Division of Water
  \- *Dam Safety Guidebook*, 1983
  \- *General Guidelines for New Dams and Improvements to Existing Dams in Indiana,* 2001
  402 West Washington Street, Room W264
  Indianapolis, Indiana 46204-2748

- Indiana Department of Natural Resources, Division of Water
  Indiana Drainage Handbook, 1996
  402 West Washington Street, Room W264
  Indianapolis, Indiana 46204-2748

- Indiana Geological Survey
  *Physiographic Divisions of Indiana***,** H.H. Gray, 2000
  Indiana Geological Survey Special Reports, SR61
  611 North Walnut Grove
  Bloomington, IN 47405-2208

- John Wiley & Sons Inc.
  Seepage, Drainage and Flownets, 1989
  Harry R. Cedergren, Author
  605 Third Avenue
  New York, New York 10158

- Kentucky Natural Resources and Environmental Protection Cabinet, Division of Water
  Guidelines for the Geotechnical Investigation and Analysis of Existing Earth Dams
  14 Reilly Road
  Frankfort, Kentucky 40601

- Marks Enterprises, Dan Marks, P.E.
  Remedial Dam Repair: Plant and Animal Penetrations of Earthen Dams
  Arden, North Carolina

- Missouri Department of Natural Resources, Division of Geology and Land Survey
  Engineering Analysis of Dams, 1989
  Maintenance, Inspection, and Operation of Dams in Missouri, 1991
  P.O. Box 250
  Rolla, Missouri 65401

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