MSHA Handbook

U.S. Department of Labor
Mine Safety and Health Administration
Coal Mine Safety and Health
October 2007

Handbook Number PH07-01

MSHA COAL MINE IMPOUNDMENT INSPECTION AND PLAN REVIEW HANDBOOK

PREFACE

This handbook sets forth procedures for the inspection of coal mine impoundments and procedures for review of impoundment plans at sites inspected by the Mine Safety and Health Administration (MSHA). This handbook supersedes the Coal Mine Impoundment Inspection Procedures Handbook Number 89-V-4, issued September 1989 with Release 2 issued October 1993. This handbook also consolidates and supersedes all Procedure Instruction Letters, Program Information Bulletins, Program Policy Letters, and Coal Mine Safety and Health (CMS&H) Memos applicable to impoundment inspections and plan reviews.

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MSHA Handbook Series
Transmittal Sheet

U.S. Department of Labor
Mine Safety and Health Administration

Subject	Handbook Number	Release Number
MSHA Coal Mine Impoundment Inspection And Plan Review Handbook		PH-07-01

1. Explanation of Material Transmitted

This revised handbook was prepared to update MSHA's coal mine impoundment inspection and plan review procedures for use by MSHA inspectors. It is consistent with current policies and incorporates the requirements of all relevant Procedure Instruction Letters. Revision of this handbook fulfills the Agency's commitment to reassess its policies and procedures concerning impoundment plan approvals and inspections subsequent to the 2000 breakthrough at Martin County Coal Corporation's Big Branch Slurry Impoundment.

2. Action Required

This Handbook **replaces** the Coal Mine Impoundment Inspection Procedures Handbook Number 89-V-4, issued September 1989 with Release 2 issued October 1993.

This handbook also consolidates and supersedes all Procedure Instruction Letters, Program Information Bulletins, Program Policy Letters, and Coal Mine Safety and Health (CMS&H) Memos applicable to impoundment inspections and plan reviews.

3. Audience

All MSHA Program Policy Manual Holders

Kevin Stricklin *10/22/07*

4. Approval Authority Date

MSHA Form 7000-7b, Sept. 88 (Revised)

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CHAPTER 1 – INTRODUCTION

I. AUTHORITY

Section 103(a) of the Federal Mine Safety and Health Act of 1977 (Mine Act), Public Law 91-173, as amended by Public Law 95-164, [30 U.S.C. § 813(a)], directs the Secretary of Labor to make inspections of underground and surface coal mines in their entirety. Impoundment facilities, retention dams, and tailings ponds are included in the definition of a coal mine in Section 3(h) (1), [30 U.S.C. § 802(h)(1)], and are required to be included in these inspections. Section 103(a), [30 U.S.C. § 813], specifies that these inspections be conducted by Authorized Representatives (AR) of the Secretary.

In addition to the Mine Act, MSHA also has responsibilities relating to protection of the general public from the dangers posed by dams associated with coal mining operations. This responsibility is reinforced by the Powerplant and Industrial Fuel Use Act of 1978. Title 42, Chapter 92, Subchapter VI, Section 8401(i) of the Regulations entitled "Protection from Certain Hazardous Actions," states the following:

> Federal agencies having responsibilities concerning the health and safety of any person working in any coal, uranium, metal or nonmetallic mine regulated by any Federal agency shall interpret and utilize their authorities fully and promptly, including the promulgation of standards and regulations, to protect existing and future housing, property, persons, and public facilities located adjacent to or near active and abandoned coal, uranium, metal, and nonmetallic mines from actions occurring at such activities that pose a hazard to such property or persons.

MSHA also has responsibilities relating to protection of the environment as per Executive Order 11514, which states in part:

> Consonant with Title I of the National Environmental Policy Act of 1969 … the heads of Federal agencies shall:
>
> Monitor, evaluate, and control on a continuing basis their agencies' activities so as to protect and enhance the quality of the environment. Such activities shall include those directed to controlling pollution and enhancing the environment and those designed to accomplish other program objectives which may affect the quality of the environment. Agencies shall develop programs and measures to protect and enhance environmental quality and shall assess progress in meeting the specific objectives of such activities. Heads of agencies shall consult with appropriate Federal, State and local agencies in carrying out their activities as they affect the quality of the environment.

II. PURPOSE

This handbook provides guidance to MSHA personnel on:

1. Inspection procedures for impoundments;
2. Inspection frequencies for impoundments;
3. Applications and interpretations of impoundment standards;
4. Hazard-potential classifications for impoundments;
5. Timeframe goals for reviewing impoundment plans;
6. Minimum levels of expertise required for reviewers of impoundment plans based on the degree of technical complexity of the plan;
7. Minimum training requirements for inspectors, impoundment specialists, plan reviewers, qualified persons, and approved instructors;
8. Inspection and administrative procedures concerning abandonment of impoundments;
9. Requirements for information/data collection for impoundments; and
10. Design features to be addressed in impoundment plans.

This handbook supersedes the Coal Mine Impoundment Inspection Procedures Handbook Number 89-V-4, issued September 1989 with Release 2 issued October 1993. This handbook also consolidates and supersedes all Procedure Instruction Letters, Program Information Bulletins, Program Policy Letters, and Coal Mine Safety and Health (CMS&H) Memos applicable to impoundment inspections and plan reviews. The memorandum tasking the committee with updating this handbook is attached as Appendix A.

Terminology in this handbook is consistent with that used in the Engineering and Design Manual Coal Refuse Disposal Facilities and by the Federal Emergency Management Agency (FEMA) in their dam safety publications.

III. BACKGROUND

The construction and operation of impoundments is a critical part of most coal mining operations. Impoundments are used for water supply, water treatment, sediment control, and the disposal of fine coal waste (slurry). A problem with the design, construction, operation, maintenance, or inspection of an impoundment can lead to a potentially dangerous release of

water/slurry. Two significant incidents have occurred in the United States involving coal waste impoundments:

- On February 26, 1972, a coal waste impoundment failed at Buffalo Creek, West Virginia resulting in the deaths of 125 people and leaving over 4,000 homeless. The area downstream of the impoundment was affected for a distance of over 15 miles. The failure occurred because of deficiencies in the design, construction, and inspection of the impounding structure.

- On October 11, 2000, a coal waste impoundment broke into an underground coal mine in Martin County, Kentucky, releasing over 300 million gallons of slurry. Slurry poured into the mine and discharged from two mine portals, contaminating miles of creeks and rivers. Fortunately, no miners were in the mine at the time of the failure, and no one was physically injured downstream. However, aquatic life was killed, environmental damage occurred, and the water supplies for several communities were disrupted. The failure occurred because the barrier between the mine workings and the impoundment was inadequate.

These incidents demonstrate the importance of MSHA's impoundment safety program and are the motivation for the development of this revised and enhanced inspection handbook.

IV. RESPONSIBILITY

The Administrator for CMS&H, through authority delegated by the Assistant Secretary for MSHA, has the primary responsibility for enforcing the Mine Act and implementing the regulations as they relate to coal mines. This responsibility is shared with the ARs in CMS&H (inspectors, specialists, and supervisors). As such, the ARs are responsible for conducting thorough inspections of impoundments located on coal mine property. CMS&H District Managers are responsible for ensuring that these inspections are conducted. They are also responsible for ensuring that design plans for impoundments are reviewed for technical completeness and accuracy and are either approved or disapproved.

MSHA's Dam Safety Program includes a Dam Safety Officer and District Dam Safety Representatives.

A. Department of Labor/Mine Safety and Health Administration (DOL/MSHA) Dam Safety Officer (DSO)

The DOL/MSHA DSO oversees MSHA's Dam Safety Program and represents DOL at meetings of the Interagency Committee on Dam Safety and the Dams Sector Government Coordinating Council, both under the Department of Homeland Security. The District Dam Safety Representatives (DSRs) and Headquarters representatives, appointed by the Administrators of Coal and MNM, along with the of the Directorate of Education and Policy Development representative appointed by the Director of EPD,

attend the Annual Dam Safety Assessment Meeting run by the DSO and provide annual written feedback to the DSO summarizing dam safety activity in each District.

The DSO also monitors all dam-related training provided by MSHA for content, coverage, and relevance. Each year, the DSO will oversee the planning and presentation of the annual Dam Safety Seminar. The agenda and presenters for the annual training seminar will be developed by the Dam Safety Training Committee. In addition, the Director of EPD will consult with the DSO regarding all dam safety training provided at the Academy, and report annually to the DSO on the coursework provided and students trained.

Based on the above information, as well as the District Office Dam Safety Reports, which will be discussed below, the DSO will prepare the Annual MSHA Dam Safety Assessment Report for the Assistant Secretary. The DSO will also use all of this information to prepare the Federal Emergency Management Agency's (FEMA) required biennial report to Congress.

The DSO is appointed by the Director of Technical Support and approved by the Secretary of Labor. The DSO is the Chief of Technical Support's Mine Waste and Geotechnical Engineering Division (MWGED), or other technically qualified individual, whose responsibilities include ensuring that the Agency's dam safety activities are consistent with the Federal Guidelines for Dam Safety, established by FEMA. To meet this responsibility, the DSO provides input to the Administrators of Coal and MNM on the Agency's dam safety activities and related directives, regulations and guidelines. The DSO's written concurrence is obtained before the issuance of any directives, regulations, or guidelines related to the Agency's dam safety program.

The DSO will conduct an annual meeting of Coal and MNM District DSRs in order to be apprised of each District's annual dam safety assessment. The DSO prepares a summary and evaluation of the Agency's annual dam safety assessment meeting, and submits an Annual MSHA Dam Safety Assessment Report to the Assistant Secretary by March 1 of each year. In addition, the report will be an assessment of the effectiveness of MSHA's dam safety activities during the previous calendar year. The report will be based on factual input and objective evidence provided in Annual District Office Dam Safety Reports and at the Annual Dam Safety Assessment Meeting, and will be prepared and organized in two parts, one part on program accomplishment, the other part on program evaluation.

The accomplishment portion of the report will:

1. Summarize accomplishments and compare these accomplishments to goals, as well as provide a description of implementation activities that have successfully addressed previous annual assessment recommendations;

2. Compare yearly accomplishments to pertinent Government Performance and Results Act (GPRA) performance measures; and

3. Summarize the status of unimplemented recommendations from previous annual assessments.

The evaluation portion of the report will:

1. Provide an assessment of the overall effectiveness of dam safety within MSHA;
2. Summarize the adequacy of general administrative and technical practices, and make recommendations as necessary for improvement; and
3. Describe MSHA's degree of compliance to applicable laws, policies and directives.

The DSO facilitates the implementation of any recommendations accepted or initiated by the Assistant Secretary that result from this report, and monitors the results.

B. District Dam Safety Representatives (DSR)

The DSR in each District is the supervisor in charge of the Coal District's impoundment safety program or specialist charged with impoundment inspections. The responsibilities of the DSRs include:

Once a year, each District DSR will prepare a District Office Dam Safety Report under the guidance of the DSO, which will be approved by the District Manager. This report will present relevant information for dam activities that have occurred during the previous calendar year. The District Office Dam Safety Report will include the following:

1. A status report on each high and significant hazard potential dam in that District; and
2. A written narrative prepared by the District DSR assessing dam safety, activities, and accomplishments throughout the District during the previous calendar year.

C. Annual Dam Safety Assessment Meeting

All topics and information contained in the District Office Dam Safety Reports will be reviewed annually at this meeting, conducted by the DSO. Each District DSR will present dam safety issues, activities, and accomplishments, and the DSO will discuss any immediate or security-related concerns. Required attendees for the Annual Dam Safety Assessment Meeting will be the District DSRs, Headquarters representatives from Coal and MNM, the Division chief or other representative(s) from Technical Support's MWGED, a representative from the Dam Safety Training Committee, and dam safety instructors or training specialist(s) from EPD.

CHAPTER 2 – ADMINISTRATIVE REQUIREMENTS

I. IMPOUNDMENT HAZARD-POTENTIAL CLASSIFICATIONS

Impoundment Hazard Potential Classification

Each impoundment is assigned a "hazard potential" classification. The classification indicates the potential for danger to life, property, or the environment, in the event of an unintentional release of water or slurry from the impoundment. Three hazard potential classifications are used, as follows:

1. **High Hazard Potential** – Assigned to impoundments where failure will probably result in the loss of human life.

2. **Significant Hazard Potential** – Assigned to impoundments where failure results in no probable loss of human life, but can cause economic loss, environmental damage, or disruption of lifeline facilities.

3. **Low Hazard Potential** – Assigned to impoundments where failure has no probable loss of human life and low economic and/or environmental losses.

It should be noted that the hazard potential classification defines the consequences in the event of a failure of the impoundment. The classification is separate from the condition of the impoundment, or the likelihood of the impoundment failing. An impoundment that is properly designed and well constructed would still be rated as having "high hazard potential" if, in the event of failure, loss of life would be likely to occur.

The hazard potential classification is important because the engineering criteria used in designing the impoundment becomes stricter as the potential for loss of life and/or property damage increases. A high-hazard potential impoundment, for example, is designed with sufficient spillway-discharge capacity, and/or storage capacity, to handle the runoff from the probable maximum flood without the embankment being overtopped. Impoundments with lower hazard classifications can be designed for lesser amounts of rainfall.

An impoundment's initial hazard potential classification is determined by the designer, subject to review during the plan approval process. If the classification assigned to a site in a submitted impoundment plan is questionable, then MSHA requires the mine operator to perform appropriate analyses to verify the areas that would be affected in the event of a failure.

MSHA inspectors need to be familiar with an impoundment's hazard potential classification so that they can take it into account during their inspections. The facility's classification is one of the items listed on the "Impoundment Inspection Form," (See **Appendix C**). During an impoundment inspection, inspectors need to verify that the facility's hazard potential classification appears accurate. For example, new construction in a previously undeveloped area near an impoundment may require that the facility's hazard potential classification be increased. If this occurs, the situation should be brought to the attention of a District Impoundment Specialist as it may indicate that the design of the impoundment needs to be modified. MSHA inspectors also need to keep in

mind that there may be underground mining in the vicinity of many impoundments. This is significant because an impoundment's hazard potential classification needs to be considered both from the aspect of water or slurry being released due to a failure of the embankment, as well as due to a "breakthrough," into an underground mine. If a "breakthrough" occurs and the coal seam is above drainage, the contents of the impoundment may flow through the mine and discharge from a mine opening or break out of the mine through a narrow outcrop barrier. In this event, the "downstream" area that is potentially endangered may not be obvious and may be different from the downstream area that would be endangered by failure of the embankment.

Another impact of an impoundment with "breakthrough" potential is that this possibility must be taken into account in the mine operator's hazard abatement plan (§ 77.216-3(e)). This plan or program must take into account the area potentially affected by the discharge from a "breakthrough" event.

II. INSPECTION FREQUENCY

A. Inspection Frequency for Impoundments during Normal Operations (Excluding Critical Construction)

1. All impoundments which are associated with active underground mines should be inspected at least once each quarter during the complete safety and health (regular) inspection.

2. All impoundments which are associated with active surface mines or facilities shall be inspected at least once every six months during the complete safety and health (regular) inspection.

3. Impoundments with "High" Hazard Potential, associated with either a surface or underground mine, shall be inspected at least quarterly. These inspections may be used as part of the complete safety and health (regular) inspection. These inspections should be conducted by an impoundment specialist.

4. Impoundments with "Significant" Hazard Potential, associated with a surface mine, shall be inspected once every six months, preferably by an impoundment specialist. Significant hazard potential impoundments that are attached to underground mines, which require quarterly inspections, shall receive two inspections by the assigned AR and the other two inspections preferably by the specialist. Inspections conducted by a specialist may be used as part of the complete safety and health (regular) inspection.

5. During periods of significant rainfall or snowmelt (based on National Weather Service Advisories), or seismic activity, supplemental evaluations/inspections should be conducted for "High" hazard potential sites. These sites should be evaluated for signs of slope instability, adequate freeboard, and proper operation of decants and spillways.

B. Inspection Frequency during "Critical Construction" at Impoundment Sites

1. The scope and frequency of the inspection(s) should be based on critical construction conditions and details as determined by the district manager. Critical construction at impoundments rated with "High" and "Significant" Hazard Potential shall be inspected by an impoundment specialist.

2. Impoundments undergoing critical aspects of construction which affect the integrity and overall stability of the site are to be considered "critical construction" sites. The approved plan should identify "critical construction" activities and require the mine operator to notify MSHA in advance of when such "critical construction" is to take place.

   The following activities are considered to be "Critical construction":

   a. Foundation grubbing in swampy, soft, or unstable conditions where provisions must be made for drainage or stabilization.

   b. Excavation and backfilling of cutoff trenches.

   c. Sealing or otherwise treating mine openings, auger holes, foundation cracks or open joints, or existing underground mine workings.
      i. Within the footprint of the dam or close enough to affect the dam.
      ii. Within or close to the basin area, as related to mine inundation or breakthrough potential.

   d. Construction of drains, filters, and placement of geo-fabrics and geo-grids.

   e. Decant System -
      i. Construction of the decant system including placement of bedding and backfill.
      ii. The installation of anti-seepage collars or seepage collection diaphragms.
      iii. Joining the pipe sections by welding, fusing, or other joining procedures.
      iv. Pressure testing.
      v. Grouting of decant pipes upon abandonment.
      vi. Construction of appurtenances such as: concrete drop boxes, anchor or reaction blocks, and headwalls.
      vii. Placement of erosion protection for decant-discharge channels which lie on or adjacent to the embankment.

   f. Construction and erosion protection for open channel spillways and diversion ditches, which are relied upon to remove runoff during the design storm.

   g. Initial push-out on a stage of an embankment using upstream construction.

   h. Any other critical phases or work affecting the integrity and overall stability of the site.

III. IMPOUNDMENT AND REFUSE PILE IDENTIFICATION NUMBERS

All impoundments are assigned a unique alphanumeric identification number that becomes the agency identifier. These numbers will be assigned by the district manager at the request of the mine operator, prior to the submittal of the initial plan.

The first two characters are the two letter U.S. Postal Service abbreviation for the state in which the structure is to be located.

The next two characters are the two digit number indicating the MSHA district in which the structure is to be located.

These first four characters are then followed by the last five digits of the Mine Identification Number to which the structure is to be assigned.

The final two digits reflect the number of the structure associated with that particular Mine Identification Number. Individual structures at a mine will be numbered consecutively (01-99). This structure identification number is unique and should not be reissued to another structure even if the structure is abandoned.

A typical structure identification number might be: KY07-01234-02

KY	07	01234	02
USPS State Postal Code	District Code	Last 5 Digits of Mine I.D.	2nd Structure at this mine

Note: Impoundments that have previously been assigned an impoundment identification number will retain their original identification number. A new identification number will also be assigned, according to the above, at the time of the implementation of the new database for purposes of the use of the database. Operators will not be required to change their existing number on identification signs or when submitting correspondence. All new sites will only be assigned a number under the new identification system.

CHAPTER 3 – INSPECTION PROCEDURES

Impoundments shall be inspected at least every quarter if associated with an underground mine, or every six months if associated with a surface mine or facility. The district manager will require additional inspections at high hazard potential sites associated with surface mines or facilities, sites undergoing critical construction phases, or where other potentially hazardous conditions are identified.

I. INSPECTION PROCEDURES (COMPLETE SAFETY AND HEALTH (REGULAR) INSPECTIONS)

Current procedures require each inspection event to be comprehensive and thoroughly documented. To document the impoundment inspection, this Handbook contains an "Impoundment Inspection Form" (See Appendix C). This form is a basic reporting instrument and contains a checklist of critical inspection items. The purpose of the form is to maximize the use of the inspector's field time and to provide critical inspection information to appropriate district personnel.

Inspectors and specialists shall use this form for documentation of inspection activities at an impoundment. The forms provide a standardized method of communicating the basic conditions observed in the field. In addition, inspectors and specialists are encouraged to photograph site conditions during the inspection, especially if any unusual or potentially significant conditions exist.

Supervisors shall ensure that all areas of an impoundment were inspected and are addressed on the form. The supervisor shall ensure that the form and/or the notes containing specific information about a potential concern or problem are forwarded to appropriate district personnel for any necessary follow-up action.

A. Pre-Inspection Preparation

1. Review Impoundment Data Sheet-Uniform Mine File (UMF)

   During the review of the UMF, the Impoundment Data Sheet or MSHA form 2000-206 located in the Impoundments and Refuse Piles (77.215 & 77.216 Imp./Refuse Piles) section shall be reviewed. This sheet contains basic information relevant to impoundment plan requirements. This information should be verified during the inspection of the site. In the event of missing information, needed clarification, or construction stage change, the district impoundment supervisor or specialist should be contacted. A copy can be made for inspection guidance.

2. Recommended Equipment

   Equipment that may be needed during an inspection includes a tape or rule, an instrument for measuring slope angles, and a camera. The tape or rule may be needed to check critical dimensions, such as the width of a spillway. An Abney level or other device may be needed to check for over-steepened slopes or measurement of freeboard, and a camera is invaluable in documenting site conditions.

B. Impoundment Inspection Form

- Each impoundment inspection must be comprehensive and thoroughly documented. This Handbook contains an "Impoundment Inspection Form", which shall be used for documentation of conditions observed during an inspection of an impoundment (See Appendix C).

- Instructions for completing the "Impoundment Inspection Form" are outlined below:

  The inspector shall complete this form to record the inspections of impoundments assigned to the mine whenever a complete safety and health (regular) inspection or technical impoundment inspection is conducted. The information is used to determine if the operator is examining the impoundment as required by the regulations, to record critical information needed by the district impoundment specialist to monitor compliance with the approved impoundment plan, and to identify problems at the impoundment which need further evaluation and/or remedial action.

  The following information, shown with a gray background on the Impoundment Inspection Form, should be completed prior to the impoundment inspection, using information available in the MSHA office as noted.

  - **Inspector's Name:** The name(s) of the MSHA CMI or Specialist conducting the impoundment inspection.

  - **Date:** The date(s) of the impoundment inspection.

  - **Event No.:** The event number under which the impoundment inspection is conducted

  - **Inspector AR No.**: The AR number of the MSHA CMI or Specialist conducting the impoundment inspection.

  - **Site I.D. No.:** The impoundment identification number as assigned by MSHA. This I.D. number is required by § 77.216-1 to be posted on a permanent marker (sign) on or immediately adjacent to the impounding structure (dam). It is shown on the Impoundment Data Sheet and MSHA Form 2000-206 provided in the UMF.

  - **Mine I.D.:** The authorized 7-digit mine identification number.

  - **Site Name:** The name of the impoundment as assigned by the operator. It is required by § 77.216-1 to be posted on a permanent identification marker (sign) on or immediately adjacent to the impounding structure (dam). It is shown on the Impoundment Data Sheet and MSHA Form 2000-206 provided in the UMF.

  - **Operator's Name:** Name of the company operating the impoundment.

  - **Mine Name:** This entry must be identical to the mine name as shown on the current Legal Identity Report.

- **Hazard Potential Classification:** "High", "Significant", or "Low". The hazard potential classification assigned to the site can be found on the Impoundment Data Sheet and MSHA Form 2000-206 in the Impoundments and Refuse Piles (77.215 & 77.216 Imp./Refuse Piles) section of the UMF. The hazard potential classification is defined in Chapter 2 of this handbook. The hazard potential classification can change with the size of the impoundment and with changes in the downstream development. If the classification doesn't appear appropriate for the conditions observed, include comments and contact the district impoundment specialist.

Items 1 and 2 below are to be obtained from examining the operator's records. Early in the inspection, the inspector should check to see that the required impoundment examinations are being made and recorded by the operator. Any apparent errors in the information discovered during the inspection should be noted in the "Comments" section of this form.

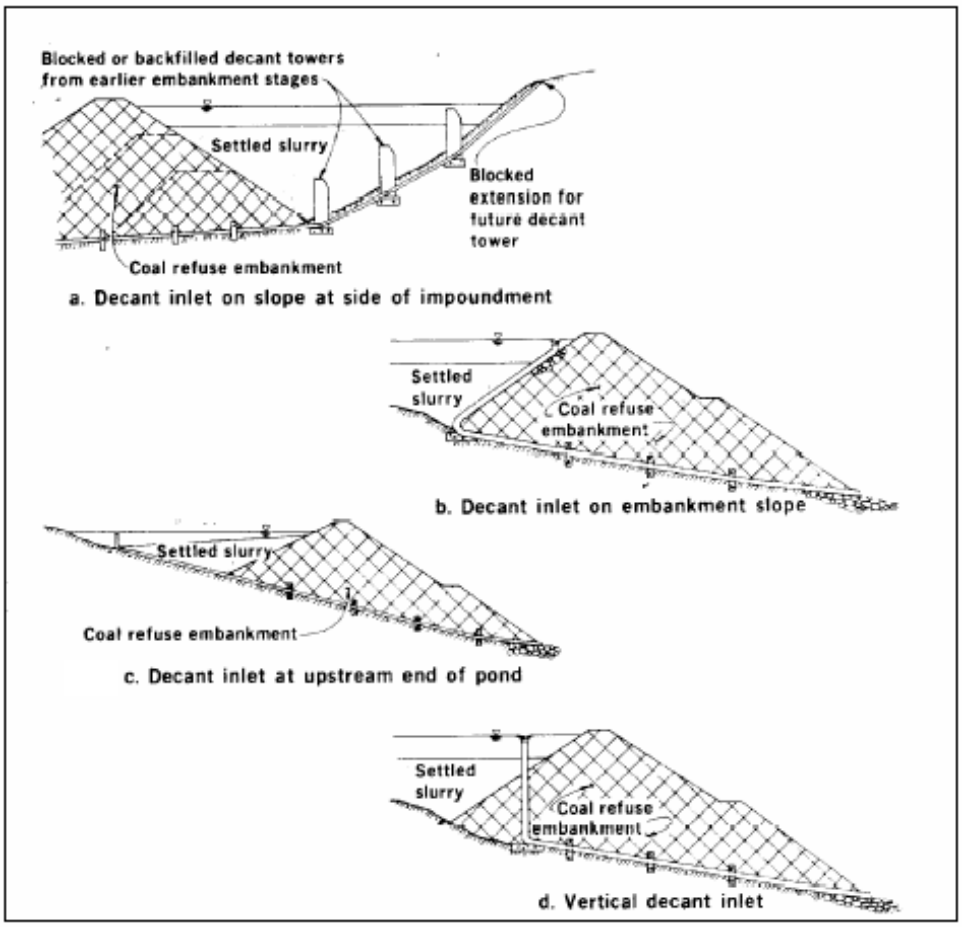
1. **Are Weekly Examinations Recorded?** Check yes or no. Impoundments are normally required to be inspected by a qualified person designated by the operator at intervals **not to exceed seven (7) calendar days**, for appearances of structural weakness and other hazardous conditions, unless otherwise approved by the MSHA district manager under § 77.216-3(a)(1). Some impoundments may have approved inspection intervals of more than seven days. The results of the inspections, including instrumentation monitoring readings, are required by § 77.216-3(c) to be promptly recorded in a book which is kept at the mine and available for inspection by MSHA. Any unusual or hazardous conditions (e.g., unexpected drops in pool level, slides of embankment material or unexpected increases in the outflow of water in adjacent mines, etc.) which are recorded should be brought to the attention of the impoundment supervisor or specialist.

2. **Are results of compaction tests being recorded?** Check yes or no, or mark "NA" for "not applicable" for those sites that have not been under construction. The results of compaction tests taken on the embankment materials should be available in the mine office and should be recorded as soon as results are available, for all dams under construction.

The elevations in Items 3 through 8 below should be available on the operator's seven-day inspection report. These elevations are needed by the district impoundment specialist to determine if sufficient freeboard is present in order to provide the storm storage capability required by the approved plan.

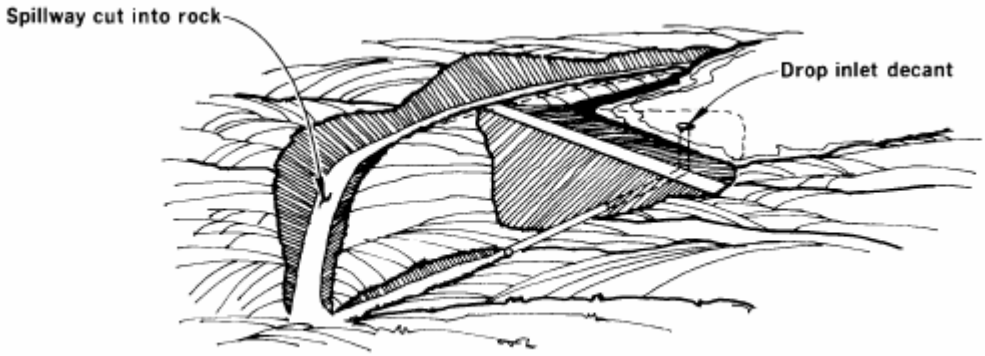
3. **Pool Elevation?** From the operator's records, note the most recent impoundment pool elevation. There may be two elevations recorded, one for the slurry delta and one for the water. If so, record both, using the "Comments" section of the form for the slurry delta elevation.

4. **Decant inlet elevation?** From the operator's records, note the elevation of the decant inlet, if the impoundment has a pipe spillway. This is the elevation at which water will begin to flow into the decant pipe.



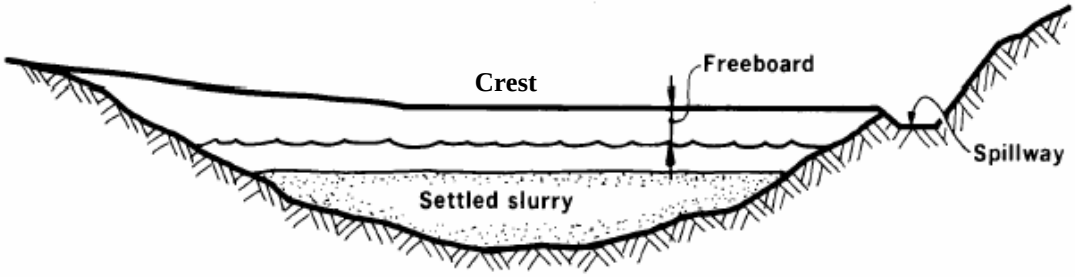
Various decant inlet configurations

5. **<u>Open channel spillway invert elevation?</u>** From the operator's records, note the elevation of the invert of the open channel spillway, if the impoundment has an open channel spillway. The invert is the elevation at which water will start to flow through the spillway channel.



Typical Spillway

6. **<u>Lowest dam crest elevation?</u>** From the operator's records, note the elevation of the lowest point on the crest of the dam/embankment.



Sectional view of embankment crest looking downstream

7. **<u>If instrumentation is present, are all required readings recorded?</u>** These readings are required by § 77.216-3 to be promptly recorded in a book. They include piezometers, weirs, settlement monuments, and inclinometers. Instruments are required to be read at intervals not to exceed seven (7) calendar days unless otherwise approved by the MSHA district manager under § 77.216-3(a)(2).

8. **<u>What is the present construction stage?</u>** The current stage of construction of the site as stated by the operator. Impoundments used only for water supply or sediment control will normally remain in their final construction stage when the dam is complete for the useful life of the facility. Slurry disposal impoundments normally will progress from stage to stage of construction for the useful life of the facility.

Items 9 – 26 are to be completed as the inspector examines the site for current conditions.

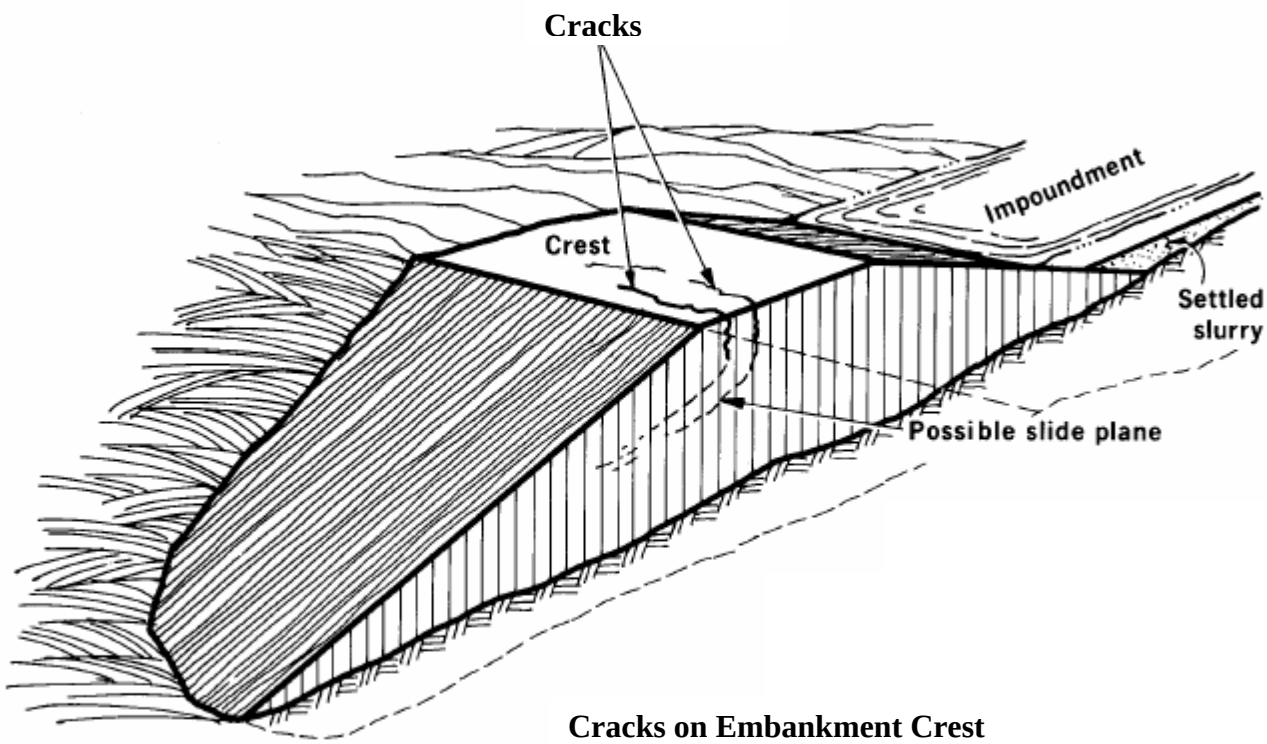
Note: When describing a condition at an impoundment, to avoid confusion when referring to the left side or the right side of a dam or impounding structure, the convention is always to use these terms with respect to an observer facing <u>downstream</u>.

9. **<u>Foundation preparation performed (i.e., removal of vegetation, stumps, topsoil)?</u>** The foundation area of a refuse embankment or dam should be cleared of all vegetation. Buried vegetation provides a weak and undesirable foundation zone. The existence of partially covered vegetation around the fringes of an embankment indicates that insufficient effort was devoted to preparing its foundation. The approved plan may also call for other foundation preparation measures to ensure stability. These may include soft soil removal, cutoff trench excavation and backfilling, or the placement of special filters in key locations. Record any locations and conditions where preparation appears inadequate in the "Comments" section of this form.

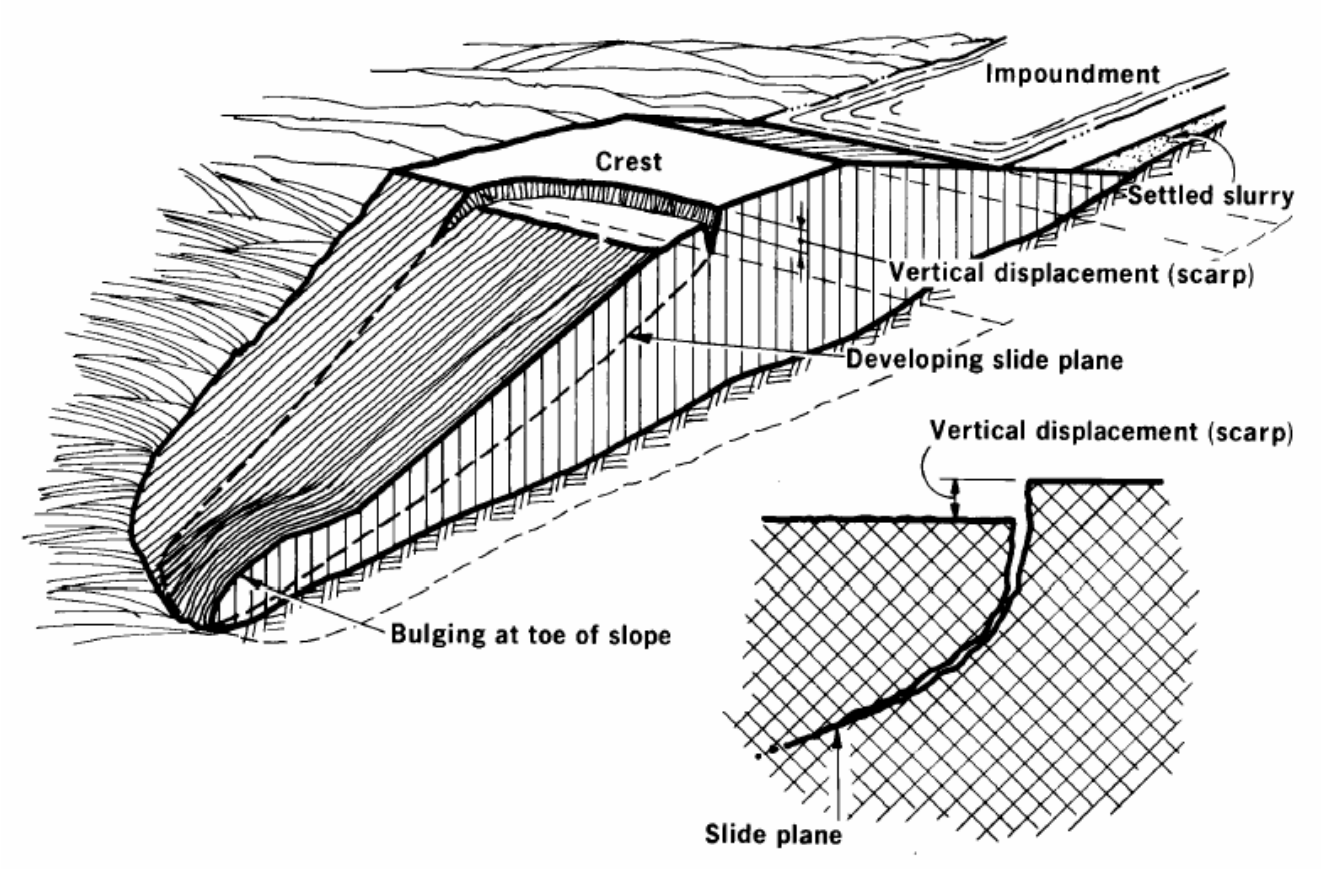
10. **<u>Lift thickness according to approved plan?</u>** Excessive lift thickness does not permit adequate compaction throughout the lift. The required lift thickness may vary for different locations on the site. The inspector should consult the Impoundment Data Sheet for the applicable lift thickness(es). The lift thickness

observed should match that recorded in the operator's compaction test records. Record locations and conditions where lift thickness appears excessive in the "Comments" section of this form. If fill placement is completed, mark as "NA" for "not applicable."

11. **<u>Cracks or scarps on crest?</u>** Cracks or scarps are indications of possible slope instability. Vertical movement (scarp) can indicate the initiation of a large slide plane. A description of the number, length and location of all significant cracks and scarps should be noted in the "Comments" section of the Impoundment Inspection Form.



Cracks on Embankment Crest



Cracks on Embankment with Vertical Displacement (Scarp)

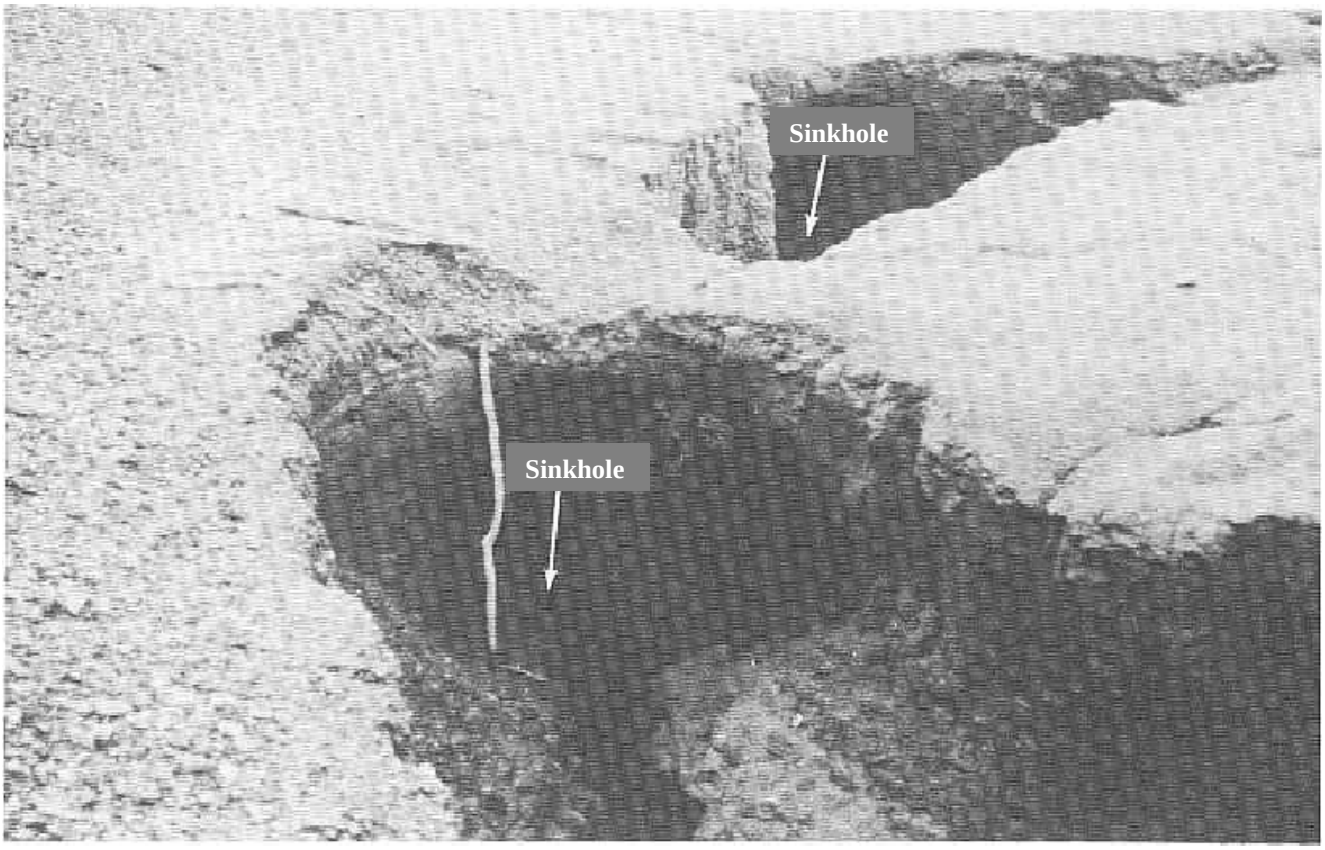
12. **<u>Is water impounded against upstream slope (slurry impoundments)?</u>** In order to minimize seepage-related stability problems at an impoundment, it is typically desirable to keep the water portion of the impounded fine refuse slurry as far away from the retaining dam as is practical. This is accomplished by locating the slurry discharge line at points along the upstream face of the dam.

13. **<u>Are decant trash racks clear and in place?</u>** If, due to clogging or some other type of malfunction, a decant is unable to operate as intended, then the overall hydraulic plan for the impoundment is impaired and serious conditions may occur. To avoid such disruptions, decant inlets are normally protected with trash racks (cage-like covers) to prevent floating logs and other debris from interfering with normal inflow.

14. **<u>Depressions or sinkholes in slurry surface or eddies or whirlpools in the pool area?</u>** These could be a signs of uncontrolled seepage through the embankment or abutment, or into an underground mine. Depressions or sinkholes occurring on the fine refuse surface may be an early indication that fines are being transported with the seepage through the natural ground into an underground mine or through the foundation, abutment, or embankment.

    The downstream slope, foundation area, and openings from adjacent underground mines, if present, should be examined for seeps, which show evidence of transported fine material. If this condition has developed, it will

have serious implications if not promptly corrected by the operator. Any depressions or sinkholes in the slurry surface, and any eddy or whirlpools in the pool area should be brought to the immediate attention of the district impoundment supervisor or specialist.



Examples of Large Sinkholes in Refuse

15. **<u>Are pumps used to remove water from the impoundment?</u>** Impoundments may have pumps to maintain the water level as low as practical, or to remove storm water inflow. If pumps are being used, the inspector should observe the general appearance of the pumps, the power source and supply (adequate fuel, etc.). The inspector should also inspect the pump discharge point to ensure that it cannot cause erosion problems.

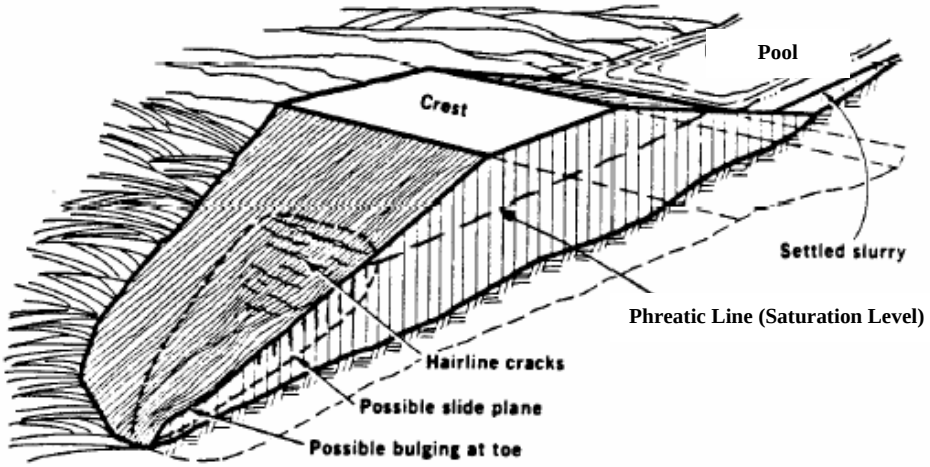
16. **<u>Clogged spillways, groin or diversion ditches?</u>** The purpose of a spillway, groin (the area where the embankment meets the hillside) or diversion ditch is to safely discharge runoff from or around an impoundment. Most spillways, groin or diversion ditches are constructed by excavating a channel through the abutment or in the natural hillside around the impoundment. When there is blockage, due to debris or from sloughing or sliding of material, channels must be cleared. If it appears that blockage may be a chronic problem, it should be brought to the attention of the district impoundment supervisor or specialist for further evaluation.

A Slide of Refuse Material and Vegetation Partially Blocking Diversion Ditch

17. **<u>Are spillway or ditch linings deteriorated or damaged?</u>** If the channel, or portion thereof, is not cut into competent rock, then erosion protection, such as a lining of concrete, riprap, grass, etc., is normally required in the approved plan. Inspect the lining material for deterioration, erosion or damage.

18. **<u>Are outlets of decant or underdrains blocked?</u>** The decant or underdrain outlet channel should provide for the safe discharge of flow away from the dam. The outlet channel should be inspected for clogging, deterioration or other maintenance problems. In some cases pipes extend from underdrains. These pipe discharge outlets should be kept free of any material that may impede the discharge.

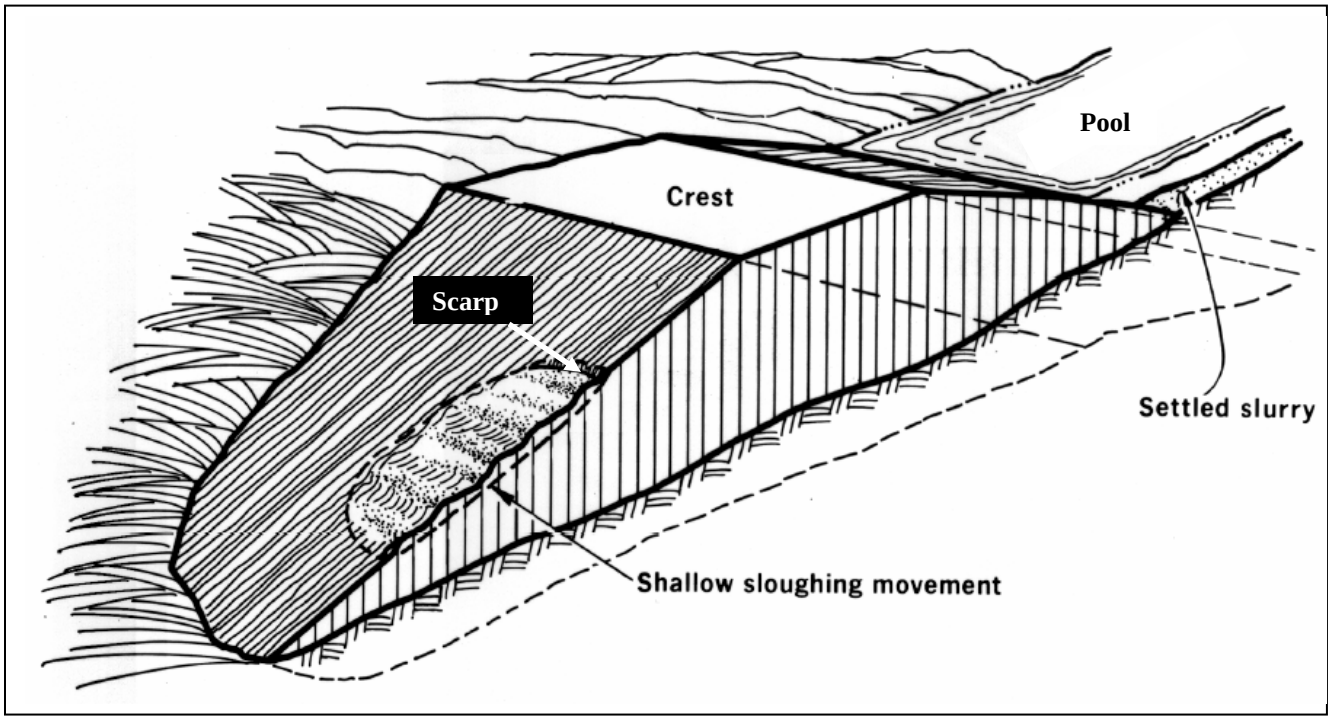
19. **<u>Cracks or scarps on slopes?</u>** Normally, such cracks will be near the top of the slope, although they can occur at any location. Vertical movement (scarp) can indicate the initiation of a large slide plane, which could move rapidly at any time. The existence of many small, short cracks, at several levels down the slope may indicate a slow or creeping movement, which is less likely to move rapidly.



Cracks on Embankment Slope Indicating Slope Movement

A description of the number, length, and location of all significant cracks and scarps should be noted in the "Comments" section of the Impoundment Inspection Form.

20. **<u>Sloughing or bulging on slopes?</u>** Sloughing is a shallow surface movement of a small area on the slope. This type of movement most frequently occurs on steeper slopes during the spring thaw period. Similar movements can often be observed along spillway cuts during the first several spring thaws after their construction.



Surface Sloughing of Material on Embankment Slope

When a large crack is observed, it indicates that a portion of the slope has moved. This movement usually produces a bulging of material at the bottom of the slide area. A bulging condition is often easier to detect than a crack, which may be disturbed and disguised by ongoing operations of the embankment surface. The most frequent bulge location is at the toe of the embankment where the slope meets the foundation. However, bulges can also occur in the middle of the slope or downstream from the toe in the foundation material. When bulging at any location is observed, the inspector should make an observation upslope from its location to locate a corresponding crack at the top of the slumped area. The accurate location of both conditions is valuable to any subsequent technical review.

The inspector should note the presence of any significant cracks, bulges or surface movement of material in the “Comments” section of the Impoundment Inspection Form.

21. **Major erosion problems?** Severe erosion that cuts deep gullies on either the slope surface or at the abutment can be serious. This type of erosion can become much worse during a single rainstorm. When a gully becomes sufficiently deep, support to the adjacent embankment is lost and major sliding can occur. Any time an area of deep erosion is observed, its location should be noted in the "Comments" section of the Impoundment Inspection Form.

22. **Decant Pipes:**

    Is water entering inlet, but not exiting outlet? If water is entering the decant inlet, but there is no discharge (or significantly less) at the decant outlet, this is an indication of a failed pipe. This condition must be immediately reported to the district impoundment supervisor or specialist.

    Is water exiting outlet, but not entering inlet? If water is exiting the decant outlet, but no water (or significantly less) is entering the decant inlet, this is also an indication of a failed pipe. This condition must be immediately reported to the district impoundment supervisor or specialist.

    Is water exiting outlet flowing clear? If the water discharging from the outlet is discolored and no discolored water is entering the inlet, this may be an indication of internal erosion and/or pipe failure. This condition must be immediately reported to the district impoundment supervisor or specialist.

23. **Seepage: (specify location, appearance (clear, muddy, carrying fines, etc.), and approximate flow rate in comments below).** It is virtually impossible to eliminate seepage from impounding embankments or dams, but it is possible to control seepage. The most critical aspect of inspecting for seepage is not only to locate the existence of the seepage flows, but also to compare the amount of flow, and the presence of particulates in such flows from one inspection to the next and to verify trends of such over time. Any significant changes should be brought to the attention of the district impoundment supervisor or specialist.

    From underdrain? Seepage through an embankment is anticipated, and an internal drain is normally installed to collect the water before it surfaces on the downstream slope. The drainage material may extend to the downstream slope, or a pipe may be placed within the drain to collect and discharge the water away from the slope. The inspector should become familiar with the location of any underdrains or underdrain pipes exiting from a slope. Any material which impedes drainage, such as material that has sloughed over the drain outlet, or any damage to outlet pipes due to crushing, clogging or corrosion should be reported.

    At isolated points on embankment slopes or along outside of decant pipe? Seepage through an embankment may be localized at a single-point source which then flows down the slope to the embankment toe. This type of seepage is detected by observing any movement of water and tracing it up

the slope to its source. Another important place to check for seepage is along the outside of any decant or spillway pipe which passes through a dam. If the pipe was not properly installed, this area can provide a path for uncontrolled seepage and internal erosion of the dam.

From the natural hillside downstream of the embankment? This type of seepage is often difficult to detect because surface runoff is collected in this area, disguising seepage points. Abutments should be inspected during dry periods when surface drainage is not present. Water flowing along the groin should be traced upslope to determine its source.

Over widespread areas on the downstream slope? When seepage occurs over a large area, it may be difficult to detect because the flow at any one point is too small to cause a traceable uphill pattern. Indicators of this type of condition can be change of color, soft areas, and changes in vegetation. The unusual height or thickness of vegetation may indicate that the area is being irrigated by seepage. Areas where vegetation has died may also indicate seepage with a high acid content. Many times seepage is easier to locate in the winter, when the seeping water melts snow more quickly than on adjacent areas. Often when there is no snow and very cold temperatures, seepage can cause a buildup of ice on the slope surface.

From downstream foundation area? Large zones of saturation in the downstream foundation area may indicate a stability problem. These can be indicated by standing water or soft, wet areas during dry times or seasons. Changes in saturation areas indicate concerns and any of these should be noted on the form.

Are there "boils" beneath stream or ponded water? Another serious indication of downstream foundation seepage and possible internal erosion is the formation of boils in the saturated areas. These distinctive features have the appearance of small volcanoes formed by transported particles accumulating at the point where seepage is emerging. Boils normally occur in the flatter portion of the downstream valley floor. A special inspection effort must be made to detect this type of seepage when it occurs under water in either a shallow stream or in a ponded area.

24. **Surface movements in valley bottom or on hillside?** The inspector should look carefully for any signs of downstream foundation movement. It can be indicated by a bulging movement, where the foundation material is pushed upwards. Some of the more common indicators of foundation movement are steeply-rising ridges that can vary in height from six inches to several feet and run parallel to the toe of the slope. Other indicators include the unnatural tilting of trees or other vegetation.

25. **Water impounded against downstream toe?** The presence of water against the downstream toe could result in instability of the embankment if this condition was not considered in the plan. If this condition is observed, it should be noted on the form.

26. **Breakthrough-potential related observations:**

Are underground mines adjacent to or beneath the pool or embankment? This can be determined by reviewing the mine maps or conferring with the district impoundment specialist.

Are there any signs of subsidence in the area? The area surrounding the impoundment should be observed for depressions, sinkholes, cracking, or other signs of subsidence.

Are water flows monitored from mine openings? Disturbance to the ground from underground mines in the area may present the opportunity for uncontrolled seepage from the impoundment. Since such seepage may be an indicator of breakthrough potential, water flow from mines adjacent to impoundments should be monitored at mine openings. Also, a written record of flow rates should be maintained by the operator, which is typically required by the approved plan. The inspector should observe the flow for discoloration, the presence of particulates, or changes in the flow rate. Review the record book to determine if any unusual change in either the appearance of the flow, the presence of fines, or the flow rate has occurred. Any unusual changes in the discharge should be brought to the attention of the impoundment supervisor or specialist.

II. INSPECTION PROCEDURES (IMPOUNDMENT SPECIALISTS)

A. Pre-Inspection Preparation

1. The impoundment specialist should review the relevant portions of the approved engineering plan, information in the UMF relative to the impoundment, and the impoundment inspection forms completed since the previous inspection. While making this review, the specialist should check MSHA Form 2000-206 (Impoundment and Refuse Pile Information) to ensure that it is current.

2. Equipment that may be needed during an inspection includes a tape and rule, an instrument for measuring slope angles, and a camera. The tape and rule may be needed to check critical dimensions, such as the width of a spillway. An Abney level or other device may be needed to check for over-steepened slopes or measurement of freeboard, and a camera is invaluable in documenting site conditions.

   In addition to the above, equipment that may be needed includes: handheld spotlight, digital rangefinder, Global Positioning System (GPS), water level indicator for checking the depth to water in piezometers, clear container, binoculars, calculator, altimeter, and calibrated bucket.

3. In addition to checking for hazards and signs of instability, an important aspect of the inspections performed by impoundment specialists is to determine whether an impoundment is being constructed in accordance with its approved plan. To determine compliance with the approved plan, specialists need to review and familiarize themselves with the key plan requirements and “critical construction” items for comparison with the field conditions they

will observe during their inspection. **The critical construction items for each stage should be noted on the Impoundment Data Sheet**. The following is a guide that summarizes the key construction requirements contained in most plans.

a. Embankment Construction

- Foundation and Abutment Preparation: The approved plan will include provisions for preparation of the embankment's foundation area. This may include requirements for removing vegetation and weak material, treating any open joints or fractures, and excavating a cutoff trench. These requirements, including cutoff trench size, backfill material, compaction specifications, and the placement of any filter zones, should be noted.

- Embankment Crest: The crest elevation and width will be specified for each stage of construction.

- Slopes and Benches: The plan will specify the steepness of the upstream and downstream slopes of the embankment, the vertical spacing and width of benches, and provisions for surface drainage and control of erosion.

- Fill Compaction: The plan will specify the type and gradation range of the embankment construction materials and the maximum thickness of compacted lifts. The plan will also specify the minimum density of compacted material, the range of allowable moisture content during compaction, and the frequency at which field density testing will be conducted. Plans should also stipulate how often tests will be conducted to verify that Proctor compaction curves are representative of the fill material being used.

- Groin Ditches: The plan will include the design of ditches to intercept hillside runoff, and collect runoff from benches.

- Initial Lift of Upstream Construction: Plans involving upstream construction should address the procedure for establishing a safe initial push-out. Any requirements for installing and monitoring piezometers and any specified maximum allowable piezometric levels underneath the push-out should be noted.

- Internal Drains: The plan will specify the location, dimensions and slope of internal drains, as well as the type and gradation of drainage aggregate. The aggregate will normally be surrounded by a filter medium, which may be a graded material or a geotextile. The plan will specify a gradation range and thickness for graded filter material. If a geotextile is used, its properties, such as its effective opening size, must match the specifications in the plan. The plan will also include provisions for preventing damage to the geotextile during placement and for overlap or closure at seams. Provisions to discharge the seepage collected by internal drains, such as via outlet pipes, should also be noted. Also, note pipe size and required materials.

b. Decant or Culvert Installation

- Pipe Characteristics: The plan will specify the material, diameter, and wall thickness or gauge of any decant pipes. The type of joints and any required corrosion protection will also be specified.

- Bedding and Backfill: Specifications will be provided for the material and dimensions of the bedding underneath the pipe and the backfill around it. Specifications for the maximum lift thickness, minimum density, allowable moisture content range, and frequency of compaction testing should be noted.

- Seepage Diaphragms or Collars: Measures to control seepage that occurs along a pipe and through the pipe's backfill will be specified in the plan. Typically, a drainage diaphragm is specified. This zone of suitably graded granular material surrounds the pipe to collect and discharge seepage. The location of the diaphragm, its dimensions, the type and size range of the granular material, any filter zones, and the diaphragm drainage outlet should be noted. In lieu of diaphragms, the use of anti-seepage collars may be specified in some plans. If collars are specified, their material, size, number, spacing along the pipe, and provisions for a watertight connection to the pipe, should be noted along with any special compaction requirements.

- Riser or Pipe Inlet: The plan should specify the materials, dimensions, and foundation requirements for any decant riser. Pipe inlets should have a trash rack and an anti-vortex device (e.g. a vertical plate) may be specified. The elevation of the decant or culvert inlet is critical in plans where the pipe is relied upon to keep the pool low enough to store the runoff from the design storm or to pass runoff through the impoundment. Where multi-level decant inlets are used, any requirements for sealing off the lower decant inlets when the pool level rises should be noted.

- Thrust Blocks: The plan should specify the size and location of any thrust blocks needed at elbows or other significant changes in direction of the decant pipe to resist the thrust forces and prevent separation of pipe joints.

- Pressure Testing: For plans specifying decant pipes that will flow under pressure, specifications for the pressure testing, such as the maximum test pressure, test duration, and test acceptance criteria, should be noted.

- Deflection Testing: Plans may include requirements that tests be performed when the pipe is installed and as the fill reaches certain heights above the pipe, in order to insure that the amount of pipe deflection is within acceptable limits. Any such requirements should be noted.

- Outlet Erosion Protection: The plan should specify the type of erosion protection material to be used and the extent of protection to be provided at the outlet of the decant pipe.

- Open-Channel Emergency Spillway: Plans that include open-channel spillways will specify, for each stage, the invert elevation, bottom width and profile, and steepness of side slopes. The plan may indicate that the spillway will be cut into rock or it may specify an erosion-protection lining. For linings, note the type of material; any bedding, anchorage, and weep-hole requirements; and the area and depth to be covered.

- Required Freeboard: For a given crest elevation, the plan will indicate how high the pool level can rise so that the embankment is not in danger of being overtopped during a large storm. In some plans, a graph is provided where the crest elevation is plotted versus the allowable pool elevation. The freeboard requirements for the plan should be noted.

- Diversion Ditches: Diversion ditches are typically only intended to intercept the runoff from smaller storms and are not considered in routing the runoff from the design storm through the impoundment. Where a diversion ditch is relied upon in the routing, the ditch must be constructed and maintained to the same standards as a spillway and particular attention should be paid to the location, dimensions, and erosion protection requirements.

- Pumps: If pumps are relied upon to draw down the level of the pool after a rainfall event, requirements for the number, rated capacity, periodic testing, and energy or fuel source requirements should be noted. In addition, plans may contain requirements to use pumps to maintain the water level in the impoundment at the lowest practical level.

- Slurry Discharge: Plans for slurry impoundments should specify the location(s) from which the slurry is to be discharged.

- Instrumentation: Instrumentation required by plans may include piezometers, weirs, settlement monitors, inclinometers, and rain gauges. The type, number, and locations of instruments should be noted. Where indicated in the plan, the allowable or acceptable levels of instrument readings, and any warning levels, should be noted. The plan may require that instrument readings be plotted over time.

- Mining adjacent to and/or under Impoundments: Plans may include provisions to cope with the presence of underground, auger, or highwall mining in the vicinity of the impoundment. For any mine openings or auger holes, the specifications for backfilling, sealing, and/or providing drainage should be noted. If a plan includes construction of a barrier as a measure to prevent the impoundment from breaking into mine workings, requirements for the location, dimension, material, compaction, internal drainage, and monitoring of the barrier should be noted. In addition, where the plan requires slurry to be discharged in front of a mine barrier, the location of the slurry discharge should be noted. Attention should also be paid to any plan requirements for monitoring the outflow from underground mines as a method for evaluating the effectiveness of breakthrough prevention measures.

- Hazard Potential Classification: The hazard potential classification for which the impoundment is designed should be noted. If an impoundment has a "low" or "significant" hazard potential classification, then the downstream development considered in the plan should be noted for comparison with the conditions observed during the inspection.

- Watershed Conditions: The watershed conditions used in the plan's hydrologic analysis should be noted for comparison with conditions observed during the inspection. For example, the amount of runoff from a watershed that is wooded versus one that has been surface mined can differ significantly.

- Engineering Supervision and Quality Control: Plans typically include requirements that critical phases of construction, such as the installation of a cutoff trench, decant pipe, or an internal drain be more closely monitored by an engineer knowledgeable of the plan requirements. Any specific plan requirements for ensuring the quality of construction should be noted.

- Other plan requirements: Some plans may have special requirements not covered by the information provided above. Any special or unusual plan requirements should be noted.

B. Impoundment Specialist - On-Site Inspection

The listing of the key plan requirements above will be a useful aid for evaluating field compliance with the approved plan during the inspection. Basic requirements from the impoundment plan for the site's configuration, compaction, and instrumentation are summarized in the "Impoundment Data Sheet," which is completed by the person who reviewed the plan.
The Impoundment Specialist's evaluation of site conditions for hazards and signs of instability will be similar to that conducted for complete safety and health (regular) inspections, but will be done in more detail. The specialist should:

- Complete the "Impoundment Inspection Form" during this inspection. The more in-depth nature of the specialists' inspection, however, will typically require more extensive note-taking than can be accommodated on that form.

- Talk to equipment operators, as they may be a good source of information about problem areas and construction conditions.

- For sites where construction occurs on multiple shifts, some inspections should be made on alternate shifts.

The impoundment specialist is encouraged to photograph site conditions during the inspection, especially any unusual or potentially significant conditions. Site conditions that will eventually be buried, such as foundations, abutments, and cutoff preparation areas, as well as the installation of decant pipes and internal drains, should be photographed.

The following information provides more detailed guidance to impoundment specialists for conducting on-site impoundment inspections for hazards and signs of instability and for compliance with the approved plan. Note that the first three items involve the review of the operator's records, which is typically performed at the mine office before going to the impoundment. The order of the remaining items is designed to follow a rough inspection route starting on the embankment's crest, proceeding to inspect areas upstream of the crest, the downstream slope area, and finally the area below the downstream toe of the structure.

Records of Operator Impoundment Examinations

- The operator is required to conduct an examination and monitor instrumentation at intervals not to exceed seven (7) calendar days, unless longer intervals are approved by the district manager. Records of these examinations are required to be kept in a book available at the mine and should include any noted appearances of structural weakness and other hazardous conditions as well as records of instrumentation monitoring. The examination records should be reviewed going back to the date of the last inspection by a district impoundment specialist or over the last twelve months.

- Any hazardous or unusual conditions recorded in the examinations, as well as any corrective actions taken or not taken, should be noted so that the condition or area can be evaluated during the on-site inspection.

- Records of instrument readings (piezometer levels, settlement measurements, weir readings, mine discharge locations, etc.) should be reviewed and compared to requirements in the approved plan. The Impoundment Specialist should make a record of any readings that appear unusual or noteworthy or ask the operator for a copy of those records.

- Where instrument readings are taken, the plan may require that these measurements be plotted over time to determine whether further investigation or action is necessary.

- Typically, each piezometer will have a maximum allowable water level or pressure given in the approved plan. The current readings should be compared to the maximum allowable readings.

- Determination of the water level from the records might require:

  a. subtraction of the recorded depth to water from the elevation of the top of the piezometer
  b. conversion of water pressure at the tip of the piezometer to feet of water and addition of this value to the tip elevation of the piezometer.

Records of Compaction Testing Results

- Records of the densities, moisture contents, and lift thicknesses determined during compaction testing should be compared with the compaction requirements of the approved plan. Different zones within the embankment may have different compaction and compaction-testing requirements.

- The frequency of density/moisture testing should be compared with the testing frequency required in the approved plan.

- Plans typically require periodic Proctor laboratory density testing to help ensure that the adequacy of compaction is being evaluated using an appropriate Proctor curve. The required frequency of this Proctor testing is usually based on volume of fill placed, and/or the number of field density tests that have been conducted, since the last Proctor testing. Proctor testing should also be conducted if a significant change occurs in the appearance of the material being placed. The Proctor testing frequency requirements in the plan should be compared to the number of field density tests since the last Proctor was done. The operator must have records of Proctor laboratory density results.

Current Impoundment Configuration

- The operator should have records of the current impoundment configuration, including the pool elevation, decant inlet elevation, emergency spillway invert elevation, and the lowest elevation of the embankment crest.

- The current configuration should be compared with the approved plan for the current stage.

- Typically, the vertical distance between the minimum crest elevation and the decant inlet elevation should be checked against the approved plan to ensure that the impoundment can handle the design storm with adequate freeboard in its current configuration.

Downstream Conditions

- An impoundment is assigned a hazard-potential classification based on the extent of downstream development. For sites with a classification other than high-hazard potential, if downstream development occurs after the facility is constructed, then a change in the design and spillway size may be required to provide more downstream protection. For such sites, it is important that the impoundment specialist note any new construction in the downstream area, for evaluation of whether the site's hazard-potential classification, and consequently its design criteria, needs to be upgraded.

- In addition to noting all new downstream developments, an impoundment specialist should also note the abandonment or elimination of existing facilities. This may be important in the instance of abandoned mine openings or air shafts that can very quickly become overgrown with vegetation.

Watershed Conditions

The design of an impoundment is based in large part upon the anticipated amount and rate of runoff from rainfall on the watershed that drains into the impoundment. Any changes in the watershed that could bring about an increase in the amount of this runoff could cause the impoundment to be overtopped. Typical changes in the watershed that could increase runoff include logging operations; farming or surface mining; increases in residential or commercial development; and changes in the upstream road patterns that may affect the path or volume of water runoff. Changes could also involve the discharge from mine openings that flow into the impoundment. The construction of upstream impoundments, such as recreation ponds or water supply dams, would also be noteworthy since failure of these structures could affect any downstream impoundment. During the initial inspection, the watershed conditions should be verified by the specialist and any significant changes should be documented thereafter.

Crest Conditions

The crest should be inspected for cracks or scarps. Excessive cracking or the presence of scarps on or near the embankment crest could indicate either inadequate fill compaction or, more seriously, instability in the embankment or its foundation. As the width of a crack increases and begins to show signs of vertical displacement (scarp), and/or if cracks progressively appear farther back from the edge of the slope, the potential for the occurrence of a failure increases. Cracks running parallel (longitudinal) to the crest are more indicative of slope movement, while randomly oriented cracks may result from surface drying.
Cracks may develop transverse to the embankment. Transverse cracks develop and extend in a direction perpendicular to the length of the crest of the dam. Transverse cracking may be an indication of differential settlement. Such cracks may create an easy path for seepage through the embankment. The crest width should be measured to ensure that it is consistent with the embankment cross-section in the approved plan.

Foundation Preparation

- Construction of a new dam or of a new stage of an existing dam requires foundation preparation in the valley bottom or along the abutments, which will be detailed in the approved plan. Typically, the foundation preparation requires clearing, grubbing, and removal of combustible and compressible materials. At a minimum, this usually requires the removal of vegetation and topsoil from areas that will be covered by the embankment. The plan may require that, in places, all soil be removed down to rock and the rock examined for cracks, open joints, and soundness. Actual foundation preparation work should be compared to plan requirements.

- Once the foundation area is stripped of vegetation and topsoil, pockets or extensive areas of structurally poor or soft subsurface materials could be exposed. Depending on the specific conditions at hand, these materials must be either removed through excavation or specially compacted. In any case, such conditions must be alleviated prior to initiating embankment construction. If soft or otherwise unsuitable material is encountered or if a spring or excessively wet conditions are encountered during the foundation preparation, the type and extent of this material or condition should be documented. Unanticipated wet conditions may require the construction of a collection drain. The method of dealing with unsuitable material or an unexpected water source should be documented.

- Open joints exposed in the foundation or abutments need to be treated to prevent them from providing a path for excessive seepage or internal erosion. Typically, open joints are handled by cleaning them out and then filling them with grout. If the plan requires that bedrock be exposed and fractures be sealed, the condition of the exposed rock should be documented. The adequacy of the fracture sealing measures should be documented.

- If the excavation for a keyway or cutoff trench is exposed during the inspection, the condition of the material that the cutoff is excavated into should be documented as well as the material at the base of the trench. For cutoffs excavated into rock, the sides should be sloped back to eliminate compacting against steep slopes and the surface of the rock should be cleaned before fill is placed. The dimensions of the cutoff should be compared to the dimensions in the approved plan.

- Construction of keyway or cutoff trench should be done in a manner that does not endanger personnel working within the cut. Cut slopes should be stable against slides of material and falling material.

- Special foundation construction measures may be necessary on sites that are steeply sloping. Any overhangs should be eliminated as they prevent adequate compaction against the foundation or abutment. Failure to adequately bond embankment material to a sloping base can cause future downslope movements or allow excessive seepage and potentially lead to failure. Specific requirements for dealing with foundations on steep slopes, such as benching of the foundation, will be detailed in the approved plan.

Blanket, Toe, Spring Collection, or Internal Drain Installation

- The material used in constructing a drainage blanket normally consists of graded sand, a graded sand-gravel mixture, or crushed stone with a limited amount of fines. The drainage materials vary with each site and depend upon the grain size and characteristics of the embankment material placed above, and the grain size and characteristics of the natural foundation material under the drainage blanket. The drainage material must be hard, strong, durable, resistant to acid attack, and sized to provide adequate flow capacity. The gradation of the drain material itself or of an intervening filter layer must prevent the migration of embankment or foundation soil particles into and possibly through the drainage material. Filter or transition zones may consist of specifically graded granular material or a layer of a geotextile. To ensure that drains continue to function properly, their performance is normally monitored with piezometers and/or weirs.

- In some instances where a natural spring is located within the foundation area, a drainage collector system is often required in the plan. The intent of this type of drainage collector is to prevent spring flow from saturating embankment material by collecting it and directing it either into the embankment's main underdrain system, or past the toe of the embankment.

- With a geotextile, the specialist should be alert to any practices that could result in a tear, puncture, or gap in the fabric. For example, the material on which the fabric is placed should be fairly uniform so that the fabric does not have to bridge over large voids. Rocks should not be placed on the fabric nor equipment operated on it in a manner that could damage the fabric. Seams should be either sewn or sufficiently overlapped, and usually pinned, so that they cannot open.

- Detailed construction specifications for the installation of blanket, toe, spring collection, or other internal drains are contained in the approved plan and should be checked against the onsite construction conditions. These specifications will typically include:
    a. Drain dimensions and slope;
    b. Drain location;
    c. Aggregate(s) type and size;
    d. Type and size of material placed adjacent to the drain;
    e. Geotextile specifications, including the fabric type and installation requirements; and
    f. Drain outlet pipe material, size, and perforation pattern.

Embankment Fill Placement

- Details of the embankment fill placement should be documented. These details should include the equipment used to spread the fill and equipment used for compaction. If fill placement methods vary for different zones of an embankment, the differences should be documented.

- The approximate lift thickness should be recorded and compared to the lift thickness requirement in the plan. When fill material is dumped from trucks, notice whether the piles are spaced far enough apart to allow the material to be efficiently spread to the required lift thickness.

- If possible, observe a cycle of fill placement to see how well the material is being compacted. Soft areas or rutting or pumping of the fill surface are indications that adequate compaction is not being achieved.

- Check for evidence that lifts are receiving complete coverage of the compaction equipment.

- The method of scarifying the top of a compacted lift prior to the placement of the next lift should be observed. Adequate scarification is important to tie a lift into the lift below and to prevent horizontal seepage planes and perched water tables from developing.

- Where additional fill is to be placed on an existing embankment slope, the new fill should be benched into the existing slope so that the potential sliding surface is eliminated, the materials are tied together, and the new fill is compacted against a horizontal surface.

- In embankments constructed using coarse coal refuse, the material on the crest may become broken down from weathering and from equipment traffic, resulting in a top layer of smooth, fine, highly-compacted, low-permeability refuse. In such cases, before placing additional layers of fill to raise the crest elevation, it is advisable to remove the top layer.

- Density testing should be observed, whenever possible, and questions should be asked to determine how the tests are conducted. It is important that density testing be conducted so that information is provided on the density and moisture content for the entire lift thickness.

- Questions should be asked about how the locations for compaction tests are selected. Test locations should be random and representative of the compaction being achieved over the entire compacted lift. In addition to testing in random areas, tests should be conducted in any areas where there is suspicion that compaction may not be adequate.

- Whenever a test shows that the compaction specifications in the approved plan have not been met, check what actions are being taken to correct the situation. If the minimum density is not met, additional passes of the compaction equipment may correct the problem. If the moisture content is out of specification, the material will need to be re-worked until the moisture is in compliance. The moisture content of the material during compaction should be within the range given in the compaction specifications.

- The embankment fill and the crest area "should" be checked for oversize material such as large rocks, which might hinder adequate compaction.

- The embankment fill and the crest area should also be checked for the presence of extraneous or combustible material. This material should be removed before additional fill is placed.

- Particular attention must be given to the placement of combined refuse. Due to its high water content, combined refuse can present handling and structural stability problems. Normally it must be spread out and some drying or draining must occur before it can be effectively compacted. Disposal plans involving combined refuse may have special placement procedures, which may differ in structural versus non-structural portions of the embankment.

- When fly-ash, bottom-ash, or other additives are incorporated into embankment fill material, placement procedures should be compared to plan requirements.

Upstream Push-outs or Construction of the Initial Lifts of an Upstream Stage

- The approved plan may specify the size and type of the equipment used to construct a push-out as well as the material placement procedures. The specialist should verify that the equipment being used conforms to the approved plan and is compatible with site conditions. The characteristics of the initial and subsequent push-outs should be observed to determine that the push-out procedures are not creating a hazardous situation for equipment operators.

- The weight of the initial push-out lift of embankment fill material for an upstream stage will typically sink into and displace slurry as it is pushed. The amount of slurry displaced will depend on the moisture content, permeability and strength of the slurry and will vary from impoundment to impoundment and possibly even from one side of an impoundment to the other. The initial push-out lift must be thick enough to support the equipment. In some cases, several push-outs will have to be made before the embankment fill will remain above the slurry.

- The weight of the initial push-out and subsequent lifts will also cause an increase of pore-water pressures in the slurry beneath the push-out. With time, the pore-water pressure will dissipate. However, subsequent lifts will further increase the pore-water pressure. The low strength of saturated, unconsolidated slurry, along with the increase in pore-water pressures will lead to a situation of marginal stability. If the push-out lift thickness is too great or if the subsequent lifts are constructed too fast, before enough of the pore pressure has dissipated, the pore pressure in the slurry can rise sufficiently, with a corresponding loss in slurry strength, to cause an upstream failure. The rate of construction of an upstream stage should therefore be closely tied to the pore-water pressure in the slurry. Subsequent lifts should not be started until the pore-water pressure in the slurry in that area has had sufficient time to dissipate. Piezometers are often installed near the base of the initial lift to monitor pore-water pressure in or near the slurry and to assist in determining a safe rate of upstream fill placement. The approved plan should be checked for guidance on push-out fill placement rate, allowable pore pressures in the slurry, and corresponding piezometer readings.

- Upstream push-outs will encroach upon the storm storage capacity of the impoundment. Push-outs must only be performed within the approved staging sequence of the impoundment to ensure that adequate storm storage is maintained.

Upstream Slope and Pool

- Check the upstream slope for the uniformity of the slope angle. Changes in slope angle can indicate slope instability or poor construction practices.

- Measure the upstream slope angle with an Abney level, or other measuring device, and compare this to the slope angle in the approved plan.

- Check the upstream slope for evidence of cracking, sliding, bulging, or extensive erosion.

- Estimate, as closely as possible, and record the vertical distance between the decant inlet and the low point on the embankment crest.

- Check for evidence of unusual rises or falls in the pool level. Also, check for the presence of whirlpools or eddies in the pool, which may be an indication of concentrated seepage. If observed, examine the downstream area and adjacent mine openings for corresponding seepage discharge and for the presence of fines being carried by the seepage.

Slurry Discharge Location and Slurry Surface

- Observe conditions at the slurry discharge. Note the slurry discharge location and indications of whether the discharge has been moved. If applicable, also note whether the discharge location is in compliance with the approved plan. As the slurry is pumped into the impoundment, the heavier, coarser particles will settle out closer to the discharge end of the slurry line. The water and finer material are forced farther away from the discharge point. In order to minimize seepage related stability problems at an impoundment, it is desirable to keep the water portion of the impounded fine refuse slurry as far away from the retaining dam as is practical. This is typically accomplished by locating the slurry discharge line at points along the upstream face of the dam.

- In some cases, particularly where breakthrough mitigation measures are part of the approved plan, slurry discharge may be specified at locations other than along the upstream slope of the impounding structure (e.g., along the length of the barrier).

- Check that measures are taken, if necessary, to prevent significant erosion at the slurry discharge point. Also, make a note if slurry is being discharged at a higher elevation than the decant inlet or if a significant slurry delta has formed. Slurry deposited above the decant inlet elevation reduces storm storage and could adversely affect the impoundment's ability to safely handle the design storm.

- Examine the appearance of the exposed surface of the settled fines. If this occurs, examine the downstream slope and foundation area for seeps that show evidence of transported fine refuse material. If fines are being carried out of the embankment, then a condition known as "piping" may be occurring, which can result in a cavity, and progressively more seepage, developing through the embankment. If piping has developed, it will have serious implications if not promptly investigated and corrected by the owner. Any appearance of sinkholes should be evaluated immediately.

- Visible sinkholes or eddies occurring on the fine refuse surface may also indicate that fines are being transported by water seeping into mine workings adjacent to or underneath the impoundment. If this occurs, adjacent mine openings or hillside seeps should be examined for changes in flow quantities or appearance.

Decant Installation

Decant installation is a particularly important phase of construction. A poorly installed decant can cause problems from excessive pipe deflection; excessive seepage and piping around the outside of the conduit or through a break in the pipe; or can result in a failed pipe with impaired ability to control the impoundment's normal pool level and discharge storm runoff. To the extent practical, inspections should be conducted during decant installation to check for compliance with the construction specifications.

If the decant pipe is being installed, note the following conditions and compare with the requirements of the approved plan:

- The location of the decant;
- The decant pipe material, outside diameter, and wall thickness;
- The method of joining the pipe sections;
- The method of installing the decant pipe and any handling practices which might damage the pipe;
- Any corrosion-protection measures;
- The type of bedding and backfill material being placed around the pipe, and the foundation material;
- The lift or layer thickness of the backfill;
- The adequacy of the compaction measures for the bedding/backfill in the pipe's haunch area; it is important that full contact be achieved between the bedding/backfill and the pipe;
- Compaction testing of the backfill: the load carrying capacity of flexible pipe comes from the support provided by the backfill; poorly compacted backfill may allow excessive seepage along the pipe and excessive deflection of the pipe;
- Provisions to prohibit heavy equipment from traveling over the pipe before sufficient fill has been placed to prevent damage to the pipe;
- If seepage collars are being installed, the material, dimensions, location, method of attachment to the pipe, and the method of compaction around the seepage collar;
- If a seepage diaphragm is being installed, the location and dimensions of the diaphragm as well as the type and size of aggregate, and the type and location of drain outlet;

- The material and dimensions of the decant riser(s) as well as its location and inlet elevation;

- If a decant riser section is being sealed, note the method of sealing and compare with the riser sealing specifications in the approved plan;

- The presence and type of trash rack and anti-vortex device, if required, on the decant inlet;

- The location and dimensions of concrete thrust and reaction blocks;

- If pipe pressure testing is being conducted, note test method, maximum pressure, and how long the pressure is held as well as rates of pressure loss or leakage;

- Type of erosion protection provided at the decant pipe outlet and extent of coverage of this erosion protection; and,

- Any requirements for monitoring the deflection of flexible decant pipes (flexible pipes that will eventually be buried under high fill heights are often surveyed for internal deflections, soon after installation, to establish a baseline for future deflection monitoring).

Decant Inlet Condition

- The decant inlet should be checked for signs of clogging. Clogging of the inlet can render the decant ineffective for storm routing and possibly for normal pool level maintenance.

- The trash rack and any anti-vortex plate should be checked for corrosion, structural damage and secure attachment to the pipe inlet. Trash racks need to be cleaned periodically and possibly repaired.

- If the decant inlet can be viewed close-up, the conduit should be checked for signs of cracking, crushing, corrosion or other indications of distress which may be occurring in other portions of the decant.

Open Channel Emergency Spillway Construction

Open channel emergency spillways are often cut into natural ground. The primary design criterion for the spillway is to ensure its ability to handle safely the maximum design storm flow depth, volume, and velocity without overtopping and without allowing significant erosion of the spillway to occur.

Note the following open channel spillway features and compare them with the requirements of the approved plan:

- The approximate invert elevation of the emergency spillway or the approximate vertical distance between the invert and the low point on the crest and/or the decant inlet.

- The bottom width, side slope angles, and depth of the channel at various locations; these dimensions are most critical in areas where the emergency spillway is adjacent to the embankment and where failure or overtopping of the spillway could result in flows onto the embankment.

- The approximate bottom slope of the emergency spillway, the locations where the bottom slope changes, and the approximate length of the spillway for each bottom slope.

- Erosion protection measures:
    a. The location, extent, and type of erosion protection measures should be documented.
    b. A bend in the emergency spillway's alignment typically requires that the erosion protection extend farther up the side slope on the outside of the bend.
    c. If a section of the emergency spillway is specified to be excavated into rock, the presence and condition of the rock should be verified.

- Where a concrete lining or a concrete-filled fabric lining is specified:
    a. The type and size of lining as well as the method and details of the lining anchorage should be checked against the specifications in the design plan.
    b. The material under the lining, and any filter layers, should be prepared as called for in the plan.
    c. The extent of the lining should be verified.
    d. Particular attention should be paid to requirements for burying the lining at its inlet and along its edges.
    e. If reinforced concrete is being laid, reinforcement should meet requirements in the plan specifications.
    f. The design plan specifications often require a minimum number of samples to be taken during each pour for strength verification testing.
    g. Concrete and concrete-filled fabric liners often require the installation of "weep" holes to prevent the build up of excessive pressures under the liner.
    h. Reinforced concrete and concrete-filled fabric liners should be inspected for signs of excessive cracking, spalling, or deterioration.

- Where riprap is used for erosion protection, compare its condition to the specifications in the approved plan, including the following:
    a. Rock type: easily weathered rocks such as shale are not suitable and only durable rocks should be used. The design plan usually includes a rock-type specification and abrasion and soundness laboratory testing is often done to ensure the durability of the riprap.
    b. Rock gradation: riprap rock size gradation will be included in the design plan and the rock being placed should be visually checked for presence of fines, amount of gravel size material and for largest rock size. Riprap should be installed so that the smaller pieces of rock are worked into the spaces between the larger pieces of rock.
    c. Bedding: riprap is typically placed over a filter bed and/or geotextile fabric to hold the material beneath the riprap in place and allow for drainage.
    d. For grouted riprap, specifications include the type and strength of grout, consistency or slump of grout, and the minimum depth of grout penetration into the riprap. Grouted riprap normally includes the installation of "weep" holes to prevent the build up of excessive water pressures underneath the riprap.

- Since required layers under an erosion lining, as well as trenches and other anchorage measures are not visible after construction, to the extent practical, inspections should be conducted during spillway construction to check for compliance with the plan specifications.

- Construction of spillway cuts should be done in a manner that does not endanger persons working within the cut.

- Check that the ground above the emergency spillway is sufficiently stable to prevent slides or falls of significant volumes of material. A slide or fall of material into the emergency spillway could cause blockage and possibly allow the emergency spillway, or the crest of the embankment, to be overtopped during a large storm. Rockfalls could also damage erosion protection.

- Overhanging trees can create a potential spillway blockage hazard during design storm conditions and trees should not be in a position where they might easily be blown or toppled into the emergency spillway.

- Any blockage should be cleared from within the emergency spillway.

- "Weep" holes should be clear and free of debris.

- Low flow, low velocity spillways may require a stand of vegetation as erosion protection. If vegetation is specified, it should be the right type and not allowed to be overgrown with unwanted trees and plants and the vegetation should be maintained.

- The open-channel emergency spillway should be extended far enough downstream so that spillway flows will not contact, erode, or in any fashion adversely affect the stability of the impounding embankment. Also, the discharge from the emergency spillway should not be located or aligned so that design storm flow discharge might endanger people or structures downstream.

<u>Pumps</u>

- Pumps may be used to maintain normal pool levels below the decant inlet. This decreases the likelihood of a black water discharge during smaller storm events. The approved plan should be checked to determine if the normal use of pumps is required.

- When pumping is required by the approved plan to maintain normal pool levels, the type, number and capacity of each pump being used should be checked against plan requirements. Pump breakdowns should be handled in a timely manner.

- If pumping capacity is required for drawdown of the design storm pool, the availability of the proper number and capacity of pumps should be verified. Such pumps are typically required to:
    a. be kept either on site or nearby.
    b. be operated upon installation, for a sufficient length of time to ensure proper operation of the system;.
    c. be periodically activated for a short time to ensure that damage has not occurred within the system.
    d. have an internal combustion engine that is either coupled to the pump or to an adjacent generator specifically for the pump.
    e. have the internal combustion engine's fuel supply stored in a specified manner.

Diversion Ditches

- Diversion ditches are rarely relied upon for discharging a portion of the design storm runoff. If diversion ditches are depended on to route a portion of the design storm flood, the ditches need to be designed for passage of the same storm used in the open-channel emergency spillway design and the ditches need to be constructed and maintained with the same level of care as the emergency spillway. In this case, the inspection should check the same details discussed in the emergency spillway section including; integrity of the erosion protection (vegetation, liner, or rock surface), the extent of the erosion protection, and blockage or potential blockage of the ditch.

- More typically, diversion ditches are installed to prevent water from smaller storms from entering a slurry pond. These ditches should be clear and free of obstruction, slides, and excessive erosion. The discharge from diversion ditches should not cause erosion in critical areas around the embankment or the impoundment appurtenances.

Mining Adjacent to or Under Impoundments

- The specialist should become familiar with mining conditions in the impoundment area from the design plan. This knowledge can then be used onsite to determine what areas might be most critical for signs of subsidence or underground mine discharge. The plan will also contain information related to required subsidence monitoring, mine pool level monitoring, and mine water discharge monitoring points.

- Where a compacted barrier is being placed between the slurry disposal area and a hillside to prevent a breakthrough into underground mine workings, the barrier is to be placed, as the embankment fill is placed, according to placement specifications in the approved plan. The plan will specify:
    a. the width of the barrier: if the barrier is not constructed sufficiently wide it may not provide the breakthrough protection intended; if it is too wide and it is built above the decant inlet elevation, it may reduce the impoundment's storm storage;
    b. the starting (lowest) elevation of the barrier;
    c. the top elevation of the barrier;
    d. fill lift thickness, minimum compaction density, and moisture content; and
    e. details for internal drain installation including drain location, dimensions, aggregate and filter specifications, and the drain outlet location and details.

- Where mine portals are located within the potential slurry pool area or within the embankment footprint, they should be backfilled and sealed, and/or drainage provided, according to the methods and specifications included in the plan.

- Where auger holes or highwall miner openings are located within the embankment footprint or where there is a potential for them to intersect mine voids, they will typically have to be backfilled and sealed, and/or drainage provided, and these measures should be constructed according to the approved plan.

- If a mine outcrop barrier is present under the dam or in the reservoir area, the integrity of the barrier area, and the overburden above the barrier, should be checked.

- Where mining has been done in the area under or adjacent to the impoundment, the area above and near the mining should be checked for signs of subsidence. This is particularly important where shallow overburden lies between the mine and the impoundment or where total extraction mining (i.e. longwall or secondary mining) or multiple seam mining has been done at any depth. Any signs of subsidence should be documented.

- Visible sinkholes occurring on the fine refuse surface or eddies in the pool may be an indication that fines are being transported by water seeping into mine workings adjacent to or underneath the impoundment. If this occurs, adjacent mine openings or hillside seeps should be examined. An unusual change in either the flow quantities (e.g. a flow increase that does not correlate to rainfall) or the appearance of the flow (e.g. carrying fines) may be an indicator of internal erosion and warrants further investigation.

Downstream Slopes and Benches

- Check the downstream slope for the uniformity of the slope angle. Changes in slope angle can indicate slope instability or poor construction practices.

- Measure the downstream slope angle with an Abney level, or other measuring device, and compare this to the downstream slope angle in the approved plan.

- The downstream slopes should not have extensive erosion. Minor surface erosion is a typical condition on most slopes before vegetation is established and final drainage ditches are constructed. While such conditions should be documented and brought to the attention of the mine operator for correction, they are not serious and are not a cause for immediate safety concern. Severe erosion that cuts deep gullies on either the slope surface or at the abutment can be serious. This type of erosion can become much worse during a single rainstorm. When a gully becomes sufficiently deep, support to the adjacent embankment is lost and major sliding can occur. Any time an area of deep erosion is observed, its location should be documented and the specialist should attempt to determine the source of water that is causing it. If the cause is not obvious, the specialist should determine if major seepage is occurring in the zone being eroded. Zones of seepage are normally more susceptible to erosion because of their water-induced softness.

- Benches should be sloped so that surface water does not run down the slope and cause erosion. Rather, each bench should drain into the abutment area and into the groin ditch. Where flows are carried through culverts, the culverts should be kept unobstructed and crushed culverts should be repaired or replaced.

- The slope should be walked and checked for signs of seepage. Seepage may be indicated by soft areas or areas of lush vegetation, dead vegetation, changes in color on the slope, rapid snow melt, or unusual ice buildup. The location of areas of general seepage should be documented as well as the appearance (e.g. clear, muddy, carrying fines, etc.) and approximate flow rate. Concentrated seeps should be carefully located on a plan drawing and the flow rate and appearance should be documented.

- Careful attention should be given to areas close to both abutments. Signs of seepage, sloughing and sliding should be documented.

- Changes in any seepage pattern, flow rate, or appearance should be documented. These changes can be the result of increased infiltration of surface rain water if it has rained recently, increased seepage resulting from the raising of the pool, or a significant change in the seepage pattern within the embankment. Photographs are a good way to compare seepage conditions over time.

- In evaluating seepage, a critical factor is whether fine particles are being carried with the flow. If particles are being carried, it is an indication of "piping," or internal erosion. Piping is a serious condition that requires prompt evaluation, as a void can be created back into the embankment that can enlarge over time and lead to failure. Observe the points where seepage emerges for the presence of fine particles in the flow. If the seeping water can be collected in a container without disturbing the material at the seepage point, examine it for color and the presence of solids.

- Small slope movements usually occur long before a larger, more observable failure. A very important part of the slope inspection involves locating any indications of these smaller slope movements. While signs of minor movement do not necessarily mean that failure is imminent, they should be technically evaluated as quickly as possible. Signs of movement that should be carefully documented, include:

    a. Cracks on the embankment slope - Normally, such cracks will be near the top of the slope, although they can occur at any location. Vertical movement can indicate the initiation of a large slide plane, which could move more rapidly at any time. The existence of many small, short cracks, at several levels down the slope may indicate a slow or creeping movement that is less likely to move rapidly. A description of the number, length and location of all observed cracks should be documented.

    b. Bulging - When a large crack is observed, it indicates that a portion of the slope has moved. This movement usually produces a bulging of material at the bottom of the slide area. A bulging condition is often easier to detect than a crack, which may be disturbed and disguised by ongoing operations on the embankment surface. The most frequent bulge location is at the toe of the embankment where the slope meets the foundation. However, bulges can also occur in the middle of the slope or downstream from the toe in the foundation material. When bulging at any location is observed, the specialist should inspect the area above the bulge to try to locate a corresponding crack at the top of the slumped area. The accurate location of both conditions is very important.

    c. Sloughing - One final type of sliding failure that has less initial importance to safety, but which can progress to a more critical condition if left uncorrected, is a shallow surface movement of a small area on the slope. This type of movement most frequently occurs on slopes during the spring thaw period.

- In addition to noting the presence of any cracks, bulges, or surface movement of material, the specialist should also describe the approximate width of each crack, its length, and any vertical displacement. The size of any bulging and the overall size of any surface displacement should be recorded. A sketch should be made of the location of each of these signs of instability, describing any observed relationship between seepage areas and bulging, cracking or surface movement. It is useful to photograph cracks, with a scale or ruler in the photograph, to document their condition and changes over time.

- Once a crack is located, some measures should be taken to monitor the crack for movement and to investigate its cause. The rate of movement provides important information on the level of significance of the crack. Monitoring the slope movement can vary from simply checking the distance between stakes driven into the ground below and above the crack, to the use of instrumentation such as inclinometers.

- Check the location and number of piezometers on the crest and downstream slope compared to the requirements in the plan.

- Vegetation on the downstream slope should be maintained so that the downstream slope conditions can be examined and the vegetation does not interfere with the inspection process. Trees should be removed as their roots can provide paths for seepage through the embankment.

Decant Discharge

- The decant outlet should be inspected for signs of cracking, crushing, corrosion or other indications of distress which may be occurring in other portions of the decant. The outlet should be clear and free of obstructions.

- The outlet end of the decant pipe should be inspected for signs of concentrated seepage on the outside of the pipe. Seepage along the outside of a decant pipe can lead to serious piping problems and is typically controlled with internal drainage diaphragms or seepage collars. Concentrated flows may indicate a problem with these seepage control measures.

- The decant outlet channel should provide for the safe discharge of flow away from the dam without significant erosion. The outlet channel should be inspected for clogging, deterioration or other maintenance problems. If the decant pipe discharges into a groin ditch, check the erosion protection, ditch dimensions and any evidence that flow has left the confines of the protected area of the ditch.

Downstream Foundation Area

- The area downstream of the embankment should be inspected for signs of instability including seepage flows or boils; foundation movement, such as bulging indicated by unnaturally tilted vegetation; and severe erosion. Such features should be documented.
- Seepage from downstream foundation areas is usually more common than seepage on the embankment slopes. This is due to the fact that the internal structure of an embankment can be better controlled during construction to minimize future seepage through the embankment. Subsurface and foundation conditions are more difficult to modify and therefore seepage may occur more readily in these downstream foundation areas.

- Seepage from the impoundment area that flows through foundation material and either emerges at the toe, or some distance downstream, can be more critical than seepage from a controlled and low phreatic line emerging on the embankment slope.

- Conversely, if seepage is caused by natural groundwater flowing through hard-rock fractures beneath an abutment, the condition may not have any effect on the stability of the embankment.

- Another serious indication of downstream foundation seepage is the formation of boil-like features in the saturated areas. These distinctive features have the appearance of small volcanoes and normally occur in the flatter portion of the downstream valley floor. A special inspection effort must be made to detect this type of seepage when it occurs under water in either a shallow stream or in a ponded area.

- The most critical aspect of inspecting for downstream foundation seepage is not only to locate the existence of the seepage flows, but also to compare the amount and appearance of such flows from one inspection to the next. Any significant changes should be documented.

- Often seepage through an embankment is anticipated, and a drain will be placed within the structure during its construction to collect the water before it surfaces on the downstream slope. The drainage material may extend to the downstream slope or pipes may be placed within the drain to collect and discharge the water away from the slope. The specialist should become familiar with the location of any underdrains and underdrain pipes exiting from a slope. Check for material which impedes drainage, such as material that has sloughed overtop of the drain outlet and check that silting has not developed at the outlet end of pipes which would restrict the flow. Any pipe damage due to crushing, clogging, or corrosion should be documented.

Foundation Movement: Simultaneous with the examination for seepage zones, the specialist should look carefully for any signs of downstream foundation movement. If this movement is linked with slope movement, it will usually occur in a horizontal direction away from the slope, or can be a bulging movement, where the foundation material is pushed upwards. Some of the more common indicators of foundation movement are sharply rising ridges that can vary in height from inches to several feet and run parallel to the toe of the slope or the unnatural tilting of trees or other vegetation.

Instrumentation: Various types of instruments are used to monitor behavior at an impoundment. This instrumentation can be placed either on the surface of a structure or within its interior, depending on the nature of the instrumentation and the monitoring requirements. The specialist should become familiar with these instruments and their location on a dam. Check that the type, number and location of instrumentation are as called for in the plan.

- Piezometers are instruments used to measure either the depth to the saturation level or the water pressure at a given depth inside the embankment. The saturation level or water pressure is compared to allowable values in the plan.

    a. An observation well, or open borehole, is the simplest type of piezometer. The water level in such a piezometer represents the contribution from all layers intercepted by the borehole.

b. Isolated tip piezometers are installed with their tips, or the point where water enters the piezometer, isolated so that the water pressure at that particular depth can be measured. That is, a zone of clean sand or gravel backfill surrounds the tip of the piezometer, and this zone is isolated by a bentonite seal above and below it. In some cases, multiple piezometers are installed in the same borehole with each piezometer tube having an isolated tip at a different elevation.
c. Pneumatic piezometers measure water pressure at the location of the tip. Pneumatic piezometers contain a transducer which is sealed in a borehole, or embedded in fill or slurry. Tubes run from the transducer to a terminal at the surface.
    - When a reading is required, a pneumatic indicator is connected to the terminal or directly to the tubing.
    - Compressed inert gas, usually nitrogen gas, is introduced from the indicator and the pressure at the transducer is measured.
    - The pressure reading is then converted to feet of water and this number is added to the known piezometer tip elevation to give the water level elevation.
d. Vibrating wire piezometers also measure water pressure at the instrument's tip. Vibrating wire piezometers have vibrating wire transducers which are typically sealed in a borehole at a specific location, but it can also be embedded in the embankment, in sand, and then covered with hand-compacted select fill, or embedded in slurry. Signal cables are routed though trenches and covered with compacted fill.
    - A readout or data-logger excites an electro-magnet in the transducer, causing the wire to vibrate at its natural frequency.
    - The same electromagnet then transmits this frequency back to the readout, where it is processed into a measurement of pressure.
    - This measurement, in feet of water, is then added to the known piezometer tip elevation to give the water level elevation.
e. Electrical piezometers consist of a sealed housing containing a pressure transducer. The piezometer is placed in a borehole or embedded in the embankment at the point to be monitored and a cable extends to the ground surface where it is connected to a readout or data-logger. The pressure transducer is a ceramic diaphragm containing a resistance strain gauge bridge. As pressure changes, the diaphragm deflects and changes the resistance of the bridge. A readout or data-logger measures the resistance of the strain gauge bridge.

f. The water level in open piezometers is measured by using a "water level indicator", which contains a probe that is lowered down the piezometer tube and registers when contact with the water surface completes an electrical circuit. The depth of the probe is indicated by depth markings on a graduated line.

g. Typically, the depth-to-water reading is subtracted from the known elevation at the top of the piezometer casing and the resulting water level elevation is compared to the maximum permissible level described in the approved plan.

h. The surface area around the piezometer should be graded and sealed to prevent surface drainage from entering.

i. Piezometer tubes should be protected with a cap or lid to prevent material or objects, which could interfere with water level measurements, from inadvertently dropping down the tube.

j. Piezometer tubes should be painted and otherwise marked to be highly conspicuous so that they are not damaged by mobile equipment.

- Weirs: The monitoring of seepage and drain discharges can provide critical information in evaluating the safety of a dam. The use of a V-notch or rectangular weir can be helpful in measuring discharges. A weir is calibrated so that the discharge over it can be determined by measuring the head of water upstream of the notch with a staff gage. Any problems with a weir, such as becoming filled in with sediment, or erosion under or around the weir, should also be documented and corrected.

- Flumes: Flumes may be used in lieu of weirs. Flumes are sized based on the expected flow to be measured. Any flow that can be channelized may be measured with a flume. Flumes should be unobstructed and maintained as originally installed.

- Pipe Discharges: Measurement of discharge at the outlet of pipes is often done for decants, drain discharge pipes, and pipes discharging water from underground mines. The specialist should note and report any pipe deterioration, clogging or other type of obstruction of the pipe outlet. Often the discharge is estimated simply by determining the time to fill a container of known volume, or by measuring the depth of flow at the outlet of the pipe. A flow estimate should be documented.

- Survey Monuments: Survey monuments, to check for settlement or movement, can be constructed in a number of ways that vary from simply driving a reinforcing rod into the embankment to constructing more permanent type monuments of poured concrete with protective covers. Monuments should be installed deep enough that they are not affected by freezing and thawing. Monument locations should be conspicuously marked to prevent inadvertent disturbance.

- Extensometers: Extensometers are used to measure bedrock movements and are usually installed in the foundation areas of the dam or other areas subject to subsidence. There are various types of these instruments. The specialist should examine the approved plan to determine the type and location of these instruments.

- Other Instrumentation: Casings or wells in which inclinometers are used to measure internal horizontal movement, settlement gauges used to measure vertical movement within an embankment, and thermocouples to measure temperatures within the embankment can be used for specific problems. A rain gauge may be specified, particularly at sites with breakthrough potential, to allow correlation between rainfall and underground mine discharges.

CHAPTER 4 – REGULATION AND POLICY

INTERPRETATION, APPLICATION, AND GUIDELINES ON ENFORCEMENT OF § 77.216

A. § 77.216 – General Requirements

Embankments Not Intended to Impound Water

Situations may arise where an embankment, which is not intended to form an impoundment, has the capability to temporarily retain water. An example would be a roadway embankment. In such cases a culvert is normally installed under the embankment to provide drainage, but when a large storm occurs, water may be temporarily retained. A potential problem is that if the culvert is undersized, or becomes clogged, then an impoundment situation may be created. If this impounded water could present a hazard, then situations with this potential need to be evaluated.

The words "can impound" must be interpreted reasonably so as to further the purposes of the Act with respect to safety. Many embankments would present no hazard even under severe storm conditions. However, under extreme circumstances some embankments have the potential to retain water above the limits specified in § 77.216 for a period of time which may impact the stability of the embankment. Since § 77.216 does not address the time period for which an embankment can impound water, the determination of whether a particular embankment is covered by the standard should be made on the basis of whether the embankment can impound water for a period of time that can create a hazard.

Some factors which should be considered in making this decision are:

1. Stability of the embankment when water is retained;
2. How quickly the culvert allows water to pass through the embankment and draw down any water temporarily retained;
3. Size and nature of the watershed area;
4. Adequacy of the embankment's drainage system;
5. Potential for clogging of the drainage system;
6. Potential for overtopping of the embankment;
7. Potential hazards downstream;
8. Depth and volume of water retained during a 100 year storm event;
9. Any other factors which may contribute to a safety hazard.

This case-by-case approach shall be used to determine whether an embankment should be classified as an impounding structure based on size or hazard potential, as outlined in § 77.216.

Measurement of Impoundment Height

To determine the elevation (depth) to which water, sediment, or slurry can be impounded, measurements should be taken from the upstream toe of the structure to the lowest point on the crest of the structure. If the lowest point on the crest of the structure is the invert of a properly designed open channel spillway, then that point is the proper location for the upper measurement. Where decant pipes and pipe spillways are used, the elevation must still be measured to the lowest point on the crest of the structure, not to the invert of the decant riser or spillway pipe.

The impoundment capacity of a structure may be based on a measurement to the invert of the spillway only if two contingencies are satisfied. The spillway must be an open channel configuration, and it must be properly designed. Where either of these requirements is lacking, the impoundment capacity of a structure must be determined based on a measurement made to the lowest point on the crest of the structure, without reference to the spillway.

The district manager is advised to require the mine operator to supply information and analyses showing that the spillway is properly designed. If this information is not made available to the district manager, then measurements should be made to the crest of the structure when determining impoundment capacity.

Impoundments permitted to remain as part of final reclamation

An impoundment that is constructed as part of the final reclamation is not subject to MSHA regulation where all mining and mining-related activities have been concluded and the site has been returned basically to its pre-mining state.

B. §77.216(a) - Plans

Impoundments in Series

In the case of multiple impounding structures which individually do not meet the size or hazard criteria requirements of § 77.216(a) where the failure of one structure can result in the failure of another, the cumulative storage capacity shall be considered for application of the standard. However, an impoundment (or impoundments) at the downstream end of a series, which does not by itself (or do not cumulatively, if more than one) meet the size or hazard criteria, would not be required to have an approved impoundment plan.

Slurry Cells

In the case of multiple slurry cells, which individually do not meet the size criteria requirements of § 77.216(a), where the failure of one cell can result in the failure of another, or where any slope failure can result in the release of water, sediment or slurry from multiple cells, the cumulative storage capacity shall be considered for application of the impoundment size criteria standard. This includes cases where an operator covers an initial slurry cell area with coarse refuse and builds additional layers of cells on top of the original set of slurry cells.

Refuse piles can have small isolated sediment control facilities, cells for the disposal of filter cake, sediment, etc., where their size would not classify as an impoundment and their location would not affect structural stability and does not impede drainage in the sense of blocking a drainage course. Where this material (filter cake, sediment, etc.), is not compacted in two foot lifts, the disposal should be approved by the district manager as per § 77.215(h).

Incised Impoundments

An incised impoundment is one created by excavating below the natural ground surface. An impoundment may be totally below natural ground, or an embankment may be constructed so that only a portion of the impoundment is below natural ground.

For the purpose of determining the size of an impoundment with respect to the size criteria in § 77.216 (a), the volume contained below natural ground is not considered. If an incised impoundment can present a hazard, § 77.216 (a) (3) should be applied.

C. § 77.216-3 - Mine Operator Inspection Frequency

Mine operators are required to conduct examinations and monitor instruments at all water, sediment, or slurry impoundments that meet the requirements of § 77.216(a) at intervals not exceeding seven (7) calendar days, unless otherwise approved by the District Manager. Although this examination is commonly referred to as a "weekly" examination, it should be emphasized that these examinations must be conducted at intervals not exceeding seven (7) calendar days.

The District Manager can approve an alternate inspection frequency program, as requested by the mine operator, to vary the frequency of required inspections of low hazard potential impoundments that have a demonstrated record of safe performance.

When the District Manager approves an alternative inspection frequency program, the provision for immediate inspection after a specified rain or a significant seismic event should be stated in the submittal. A guideline for the specified rain event would be any rainfall that is equal or greater than the one year frequency, twenty-four hour duration event for the affected area. These provisions should provide for an equal or greater degree of safety, since this immediate inspection would be required regardless of when the last inspection took place.

Furthermore, if a potentially hazardous condition develops at an impoundment, § 77.216-3(b)(4) requires the operator to examine the structure and monitor the instrumentation at least once every 8 hours, or more often, as required by an authorized representative.

"At the mine" in reference to § 77.216-3(c), for the location where records are to be maintained, is interpreted to include the mine office, preparation plant, engineering office, etc., depending on which location is closest to the site.

"One of the following persons" in reference to § 77.216-3(d) is interpreted to include the preparation plant superintendent or foreman.

D. § 77.216-3 – Recommendation Concerning Emergency Action Plans

Section 77.216-3 addresses evacuation plans for miners and sets out the examination, monitoring, hazard abatement, planning and reporting requirements for coal mine operators operating impoundments and impoundment structures within the meaning of Section 77.216(a).

Although § 77.216-3 addresses the evacuation of miners in the event that a hazardous condition develops, MSHA encourages mine operators to develop an Emergency Action Plan (EAP) for all high and significant hazard potential impoundments to protect all persons potentially affected.

The "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners," FEMA 64, dated October 1998, encourages dam owners and operators to develop an EAP for all impoundments that would likely cause loss of life or significant property damage in the event of a failure.

Guidance for preparing an EAP is provided in "Federal Guidelines for Dam Safety" referenced above. As indicated in these Guidelines, to be complete an EAP should cover the following:

- Notification flowchart – indicating who is to be notified, by whom, and in what priority;
- Emergency detection, evaluation, and classification – procedures for the reliable and timely identification of an emergency situation;
- Responsibilities – explanation of responsibilities and coordination with local authorities;
- Preparedness – actions to prevent or lessen the impact of a failure; and
- Inundation mapping – delineation of the areas potentially affected by a failure.

E. § 77.216-4 – Annual Report and Certification

District personnel shall review the annual report and certification to ensure that the impoundment is being constructed, operated, and maintained in accordance with the approved plan, and that the required information has been submitted. The annual report and certification should contain the location and type of each monitoring instrument such as piezometers, rain gauges, survey monuments, weirs, discharge monitoring points, etc. Operators should be encouraged to submit instrument readings in a graphical format for purposes of comparison. The district shall acknowledge receipt of the annual report and

should provide the due date for the next submittal. If all required information is not submitted, the operator shall be notified in writing that additional information is needed.

District personnel shall enter information from the annual report into the Impoundment and Refuse Pile Inventory database. A copy of the annual report shall be maintained in the district office and a copy shall be sent to Technical Support, Mine Waste and Geotechnical Engineering Division (MWGED).

F. § 77.216-5 - Abandonment

Impoundments are normally abandoned under this section by precluding the future impoundment of water, sediment, or slurry. Impoundments can also be left in place under an abandonment plan meeting the requirements of § 77.216-5(b). Until an impoundment is abandoned under § 77.216-5 it is still considered an active impoundment for inspection purposes regardless of the mine's operational status.

Abandonment by Precluding the Future Impoundment of Water, Sediment, or Slurry

Prior to abandoning a water, sediment, or slurry impoundment according to § 77.216-5(a), the operator shall submit a plan for abandonment to the District Manager for approval. This plan must include:

1. provisions for major slope stability which includes long term stability considerations, such as erosion control, drainage, etc.;

2. a schedule for the plan's implementation;

3. provisions to preclude the probability for the future impoundment of water, sediment, or slurry, which is typically done by breaching and/or capping.

Once the plan has been approved and the conditions met, the district shall abandon the identification number, discontinue inspection activities, and retire the records [in accordance with Federal Archives and Records Center (FARC) guidelines and timeframes].

Abandonment Plans Allowing the Continued Existence of the Impoundment

Mine operators desiring the abandonment of an impoundment, while still allowing for its continued existence, must submit a plan according to § 77.216-5(b). This plan must include:

1. a certification by a registered professional engineer, knowledgeable in the principles of dam design and in the design and construction of the structure, that the structure substantially conforms to the approved design plan and specifications and that there are no apparent defects;

2. a certification by the current or prospective owner that he/she is willing and able to assume responsibility for operation and maintenance of the structure;

3. a permit or approval for the continued existence of the impoundment from the Federal or State agency responsible for dam safety.

Once the plan has been approved and the conditions met, the district shall abandon the identification number, retire the records, and discontinue inspection activities.

Abandoned Mines with Active Impoundments

Mines or facilities cannot be placed in abandoned status by the districts if impoundments associated with those mines or facilities are still intact and are not properly abandoned or transferred as specified by § 77.216-5.

MSHA must continue to inspect the impoundment until it has been properly abandoned or transferred. Even if the mine or facility has been closed by the operator, the status of the mine or facility must remain in an active non-producing status and the impoundment must continue to be examined by the operator and inspected by MSHA. In the event that the impoundment was associated with an underground mine that is closed and abandoned, the districts should encourage the operator to abandon the underground mine identification number and apply for a surface identification number. This places it in the proper status as a surface operation.

Orphaned Impoundments

MSHA defines an orphaned impoundment as one in which there is no responsible mine operator accountable for the impoundment and where the impoundment has not been properly abandoned under MSHA standards at § 77.216-5.

If an operator has not properly abandoned the impoundment according to § 77.216-5, and is not able to conduct examinations or maintain the impoundment, the following actions should be taken:

1. District personnel shall make every effort to contact and encourage the operator of record to inspect and maintain the impoundment(s), or abandon the impoundment(s) in accordance with § 77.216-5(a).

2. An inspection shall be conducted and the inspector/specialist shall take the appropriate enforcement action and immediately notify the district impoundment supervisor of the situation. If there is no representative of the operator on-site, the enforcement action shall be sent via certified mail to the last known operator of record. If the certified mail is returned undeliverable, the violation(s) shall be forwarded to the Office of Assessments.

3. If the operator of record cannot be contacted or does not have the ability to inspect or maintain the impoundment, the district manager shall notify the Division of

Safety that this impoundment should be classified as an orphaned impoundment. The Chief of the Division of Safety will notify the U.S. Office of Surface Mining (OSM) that the impoundment has been classified as an orphan and that MSHA will no longer inspect the site.

4. If a condition is found at the site that may constitute a hazard, the district shall immediately notify the Division of Safety and request that OSM is immediately made aware of the condition. All information including violations, notes, sketches, and an evaluation of the hazardous condition(s) at the site shall be immediately forwarded to the Division of Safety.

5. After the Division of Safety has notified OSM, a mine status update shall be completed, placing the mine in a permanently abandoned status and no further inspections of the impoundment will be conducted.

G. § 77.1605(k) - Berms and Guardrails

Berms or guardrails, in accordance with § 77.1605(k), are required along the section of an elevated roadway crossing the crest of an impounding structure when the structure has been built to its final crest elevation and when the section of road over the impounding structure is completed. However, temporary berms or guardrails are not required along the section of an elevated roadway where it crosses the working surface of the impounding structure while the site is under active construction. Placement of such temporary berms or guardrails can be detrimental to the overall, long-term integrity of the structure, by impeding site drainage and interfering with construction activities.

On elevated roadways, leading to or constructed on the inclined surfaces of the impounding structure, berms or guardrails are required to be maintained as the structure increases in height.

If active construction on an impounding structure is suspended for any reason, and the roadway has not yet achieved the final elevation in accordance with the approved construction plan, then berms or guardrails are required if the site is an elevated roadway.

H. Miscellaneous - Approval of Underground Coal Mine Waste Disposal Plans

The Surface Mining Control and Reclamation Act of 1977, requires approval of an operator's underground coal mine waste disposal plan by the Mine Safety and Health Administration (MSHA) and OSM or the appropriate state agency. Therefore, MSHA shall evaluate such plans when they are received from the operator, from the state regulatory authority, or from OSM.

If the plans adequately address the health and safety of both surface and underground coal miners, MSHA must provide written notification to the originator of the plans, and copies

of the decisions must be mailed to the other concerned parties. Notification of disapprovals will be served in the same manner.

CHAPTER 5 – TRAINING REQUIREMENTS

This chapter provides guidance for minimum impoundment related training required for MSHA and industry personnel. These personnel include:

- Coal Mine Safety and Health Inspectors conducting regular inspections at coal mines,
- Engineers and Coal Mine Safety and Health Specialists conducting detailed impoundment inspections (Impoundment Specialists),
- Engineers and other MSHA personnel conducting reviews of impoundment plans (Plan Reviewers).
- Qualified Industry Persons conducting impoundment examinations in accordance with § 77.216-3(a),
- Industry Personnel conducting training courses for qualified industry persons (Approved Industry Instructors).

I. TRAINING REQUIREMENTS FOR MSHA PERSONNEL

A. Inspectors

- Initial Training – Qualification course for impoundment inspection as provided by the Mine Health and Safety Academy.
- Impoundment Inspection Refresher Training – Four (4) hours per year.
- This training can be conducted by the district impoundment supervisor or specialist; the National Mine Health and Safety Academy staff; or other qualified instructors.

B. Impoundment Specialists

- Initial Inspectors Training – Three (3) days of Qualification for Impoundment Inspection.
- Specialized Training – A minimum of three (3) days per year, which may be satisfied by attending the Dam Safety Specialist's Training Seminar or other equivalent training.

C. Plan Reviewers

- Must have knowledge and experience as outlined in Plan Complexity Review Matrix.
- Specialized Training – A minimum of three days (3) per year, which may be satisfied by attending the Dam Safety Specialist's Training Seminar or other equivalent training.
- On-the-Job Training at MWGED.

D. Dam Safety Training Seminar

Each year, the agency will conduct an annual Dam Safety Training Seminar. The agenda and presenters for the annual Dam Safety Training Seminar will be developed by the Dam Safety Training Committee, under the auspices of the DOL Dam Safety Officer. The Dam Safety Training Committee will be comprised of impoundment specialists from at least two CMS&H Districts and at least one DSR from a MNM District, representatives from CMS&H and MNM Headquarters, a representative of EPD, and at least one engineer from the Mine Waste and Geotechnical Engineering Division (MWGED) of Technical Support. Due to the extent of input that MWGED will have to provide for each annual seminar, the Dam Safety Training Committee will be chaired by a representative from that Division.

II. TRAINING REQUIREMENTS FOR INDUSTRY PERSONNEL

A. Qualified Persons

Each coal operator owning, operating, or controlling an impoundment which is required to be inspected by a qualified person must provide initial training and annual retraining for the qualified person as required by § 77.107-1(b).

In accordance with § 77.107, the training and retraining program for such qualified persons must be submitted to the appropriate district manager for approval.

- Initial Training:
  The initial course, to be at least 8 hours in duration, should as a minimum consist of the following subjects and topics:

Initial Training Course – 8 hours:

1. Introduction to Embankment Engineering and Behavior
   a. Engineering terms
   b. Failure types, including breakthrough into mine workings
   c. Effect of saturation on stability
   d. Issues concerning upstream push-outs (slurry impoundments)
   e. Relationship of hydrology and emergency discharge structures

2. Inspection Path for Impoundment
   a. Crest and slurry surface
   b. Upstream Slope
   c. Abutments, downstream slope, and toe
   d. Discharge facilities
   e. Location of critical seepage areas
   f. Location of mine openings or potential subsidence
   g. Instrumentation
   h. General site safety

3. Potentially Hazardous Conditions
   a. Seepage, piping
   b. Cracking, slumping, and bulging
   c. Fires
   d. Failure of water control structures
   e. Location of phreatic surface
   f. Subsidence, sinkholes, or the appearance of depressions on slurry surfaces or eddies in the pool
   g. Inadequate freeboard

4. Inspection Records for Impoundments
   a. Recording instrumentation readings
   b. Recording potentially hazardous conditions

In addition to the completion of the initial training, all persons must pass an examination in order to become qualified. The person must achieve a minimum final examination grade of 80%. The examination must be administered by an MSHA representative.

- Annual Refresher Training:
  All qualified persons must receive at least 4 hours of annual refresher training within twelve months from the date of the initial or last annual refresher training. Persons taking annual refresher training will not be required to take additional examinations. The annual retraining course should be a refresher of the subjects covered in the initial training with special emphasis given to areas specific to the impoundments to be inspected. This training cannot overlap with other required training. The operator must maintain a list of all qualified persons designated to perform impoundment inspections as required by § 77.106.

  The District Manager may grant requests for limited extensions of time to complete annual refresher training.

  If qualification has expired due to not receiving annual refresher training, a person must complete annual refresher training and pass the initial training examination with a score of at least 80%. The examination must be administered by an MSHA representative.

B. MSHA -Approved Industry Instructors

Any person may request to become an approved instructor for an impoundment inspection qualification course. All applicants must complete the initial 8-hour training, achieve a minimum grade of 90% on an examination administered by an MSHA representative, and meet the requirements of § 48.23(h). Upon approval from the district manager, the instructor can present the 8-hour initial training and 4-hour annual refresher training courses. An approved industry instructor may never administer the examination that qualifies a person to conduct impoundment inspections. This test must be administered by an MSHA representative.

An instructor, who is also a qualified person, can satisfy the annual qualified persons training requirement by either attending a 4-hour annual refresher course or by teaching an initial or annual refresher course. Instructors not completing the requirements for annual refresher training lose qualification for purposes of performing inspections, but may retain approved instructor status.

Instructors may have their approval revoked by MSHA if a course is not taught at least once every 24 months as per § 48.23(i).

CHAPTER 6 – MSHA IMPOUNDMENT DATA COLLECTION

MSHA is required to routinely collect, update, and report certain information relative to regulated impoundments. These responsibilities include providing information for the following:

- MSHA's Impoundment and Refuse Pile Inventory (IRPI);
- The National Inventory of Dams (NID);
- Federal Emergency Management Agency's (FEMA) Biennial Report to Congress;
- MSHA's Plan Review Tracking Data.

I. Impoundment and Refuse Pile Inventory (IRPI)

The Impoundment and Refuse Pile Inventory (IRPI) is a database that contains information about the impoundments and refuse piles which are regulated by MSHA. The IRPI is part of the MSHA Standardized Information Systems (MSIS), and is accessed from the MSIS home page. The availability of basic information on the number, location, and characteristics of impoundments is needed to respond to requests for information that MSHA receives, and to assist in managing MSHA's impoundment-safety activities. The information contained in the IRPI was developed based on specific data needs identified by Coal Mine Safety and Health, Metal-Nonmetal Mine Safety and Health, and Technical Support. The IRPI includes specific formats for conveniently preparing District level and national level summary reports. It also includes the information that MSHA is required to collect and report for the National Inventory of Dams (see below).

The information in the IRPI is to be updated at least annually by the impoundment specialists with information obtained from approved plans, field inspections, District records, and annual impoundment reports. Designated impoundment specialists will be able to add or modify information for their particular district, view data from all districts, and generate summary reports. See Appendix B for a list and explanation of the impoundment-related information that needs to be input into the IRPI.

II. National Inventory of Dams (NID)

The U.S. Army Corps of Engineers (USACE) is responsible by law for maintaining and periodically updating the National Inventory of Dams (NID). This responsibility was authorized by Congress in the Water Resources Development Acts of 1986 and 1996. Information in the NID is important for emergency management planning and coordination of public safety and security initiatives.

MSHA, as well as other Federal agencies that deal with dam safety, is responsible for providing the USACE with certain information for inclusion in the NID. In order to meet this requirement, MSHA has created a system whereby the required NID information is included within, and can be extracted from, MSHA's IRPI database. The IRPI contains the NID data, as well as other information that MSHA collects for its own purposes. Since the NID information is extracted from the IRPI, District personnel do not have to deal directly with the NID. However, it is important that District personnel keep the IRPI data updated so that correct information is supplied when the NID is updated. Requests for updates from the USACE do not necessarily occur at predetermined intervals.

III. FEMA's Biennial Report to Congress

Every two years, MSHA, and each Federal agency that deals with dams, is required to provide a report to FEMA on its dam safety program and activities. FEMA is then required, under the Dam Safety and Security Act, to compile the information and prepare an overall report for the President and the Congress. The information that MSHA must report to FEMA, each two years, includes the following:

a. Dam safety staffing level, and comparison to previous FEMA reports;
b. Dam safety training received and given by MSHA personnel;
c. Information on MSHA's dam inventory, including a breakdown of the number of dams in each district;
d. Number of plan reviews performed by MSHA personnel;
e. Number of impoundment inspections and investigations performed by MSHA;
f. A description of any dam failures or incidents, and the remedial actions taken;
g. The status of emergency action planning for the agency's impoundments; and
h. MSHA's involvement with state agencies.

The districts, National Mine Health and Safety Academy, and Technical Support (MWGED) should be prepared to provide the above information for their personnel and activities to MSHA Headquarters staff. The Administrators of Coal and Metal/Nonmetal, and the Directors of Educational Policy Development and Technical Support should forward the information for their organizations to the Dam Safety Officer. The final report to FEMA will be compiled by the Department of Labor's Dam Safety Officer.

IV. MSHA's Plan Review Tracking Database

Since MSHA-regulated impoundments are typically modified several times before they are abandoned, it is important that plan reviewers and specialists have a complete record of plan review and construction activities. In order to facilitate this, MSHA maintains plan review tracking data in an agency-wide database. This database includes entries for each plan submittal from the coal company or their consultant.

Currently, the inventory of impoundment plan submittals and the plan review tracking information are recorded in eleven separate spreadsheets, one for each coal district, on the MSHA WAN network. However, work is underway to incorporate completely this impoundment plan data into the Mine Plan Approval database, which is part of the MSHA Standardized Information Systems (MSIS), and upon completion will be available from the MSIS home page.

CHAPTER 7 – PLAN REVIEWS

I. Impoundment Plan Approval Timeframes (Goals) for the District and Technical Support

A. District Administrative Review

- The District Administrative Review is a cursory review of submitted plans to verify that the 17 items required by § 77.216-2 are included. These items are evaluated to ensure that they are addressed for the submitted plan. Plans are also reviewed for obvious errors and omissions. This review is also conducted to determine if the district will do a complete technical review of this submittal or have the plan reviewed by Technical Support.
- A district impoundment specialist shall conduct the District Administrative Review.
- The timeframe (goal) for completion of the District Administrative Review should be 2 weeks from the date the plan is received in the district.

B. Technical Review of New Plans or Major Plan Modifications

- The technical review is a complete assessment of all engineering and design aspects of the plan.
- A major plan modification is a modification to a previously approved plan that significantly affects stability, flood routing, breakthrough potential, or seepage analysis.
- The technical review shall be conducted by a qualified Civil Engineer or person trained in the principles of dam design and construction (See Plan Complexity Review Matrix to determine the knowledge/experience level required).
- The timeframe (goal) for completion of the technical review of new plans or major plan modifications should be 6 months from the date received at the reviewing office.

C. Technical Review of a Minor Plan Modification or Additional Information

- Technical reviews of minor plan modifications or additional information are assessments of the engineering and design aspects of the plan.
- A minor plan modification is a modification to a previously approved plan that does not significantly affect stability, flood routing, breakthrough potential, or seepage analysis.
- Additional Information is supplemental information submitted to support the engineering and design aspects of the impoundment, which does not change the fundamental dam appurtenances or configuration.
- The review of a minor plan modification or additional information shall be conducted by a qualified Civil Engineer, or person trained in the principles of dam design and construction (See Plan Complexity Review Matrix on Page 60 to determine the knowledge/experience level required).
- The timeframe (goal) for completion of the review of a minor plan modification or additional information should be 3 months from the date received at the reviewing office.

D. Mine Operator Notification

- If the plan or revision is acceptable, the district manager will send written notification to the operator that approval is granted.
- If the plan or revision has been determined by MSHA to be inadequate or unsuitable, the district manager will advise the operator in writing of the deficiencies of the proposed plan or revision. The operator is then given an opportunity to discuss with the district manager the problems identified and potential solutions. If the plan or revision cannot be approved, MSHA procedures established in the Program Policy Manual, Volume V, V.G-4 will apply.

II. Experience and Knowledge Required for a Plan Review

MSHA personnel who review impoundment plans need to have adequate knowledge and experience commensurate with the complexity of the plan. Guidance on plan complexity and the corresponding recommended reviewer knowledge/experience is provided below. Whether a plan is reviewed in one of the Districts, or by Technical Support, the reviewer's findings should be subject to oversight or concurrence by an engineer with the appropriate level of experience and knowledge.

A. Advanced Complexity Impoundment Plans

Examples:

- Plans where the embankment is to be raised using upstream construction (seismic stability/liquefaction).
- Plans where there are underground mine workings, highwall miner openings or auger holes beneath or adjacent to the embankment or reservoir.
- Plans for impoundments with high-hazard potential, that is, where loss of life is likely in the event of failure.
- Embankments that will reach a height of over 100 feet.

Review Level 3: Requires specialized knowledge obtained from experience and/or education **equivalent** to a Master's Degree in Civil Engineering with advanced courses in soil and rock mechanics, hydrology and hydraulics, and at least 6 years of recent experience related to dam design/construction. Registration as a Professional Engineer is recommended.

It is recommended that reviews be conducted by Technical Support, MWGED for plans in this category.

B. Intermediate Complexity Impoundment Plans

Examples:

- Plans for impoundments with significant (sometimes termed "moderate") hazard potential.

- Plans for minor modifications to high hazard potential dams.
- Plans involving the design of internal drains and filter layers.
- Plans involving pipes to be buried under more than 50 feet of cover.
- Designs involving the use of spillway liners.
- Plans involving construction on surface mine spoil.
- Plans involving special treatment of the foundation or abutment, such as grouting or cutoff trenches.

Review Level 2: Requires knowledge obtained from experience or education **equivalent** to a Civil Engineering graduate with undergraduate courses in hydrology, hydraulics, and soil mechanics, and at least 4 years of recent experience related to dam design/construction.

Plans in this category should be reviewed in the District only if the District staff has the knowledge, experience and time to identify and address all potential safety issues.

C. Lower Complexity Impoundment Plans

Examples:
- Plans for impoundments with low-hazard potential in the event of failure.
- Plans for minor modifications to significant and low hazard potential dams.
- An increase in the decant inlet level, combined with an increase in the embankment's crest elevation.
- Plans involving no upstream construction and no underground mine workings, highwall miner openings or auger holes.
- Minor changes in the geometry of the dam.
- Small increases in the height of the dam.

Review Level 1: Requires knowledge obtained from experience and/or education **equivalent** to a Civil Engineering graduate with course work in soil mechanics, hydraulics, and hydrology.

Plans in this category should be reviewed in the District if the District staff has the knowledge, experience, and time to identify and address all potential safety issues.

General Note: Copies of all correspondence related to all impoundment plans are to be sent to the Technical Support (MWGED). A complete file will be maintained at MWGED so that all of the pertinent background information will be available in the event that MWGED personnel are requested to review a plan submittal, provide assistance with a field investigation of the site, etc.

Plan Complexity Review Matrix

	Recommended Knowledge / Experience of Reviewer		
	Level 1 Reviewer: Knowledge and Experience Equivalent to a Civil Engineering Graduate with course work in hydrology, hydraulics, and soil mechanics.	**Level 2 Reviewer:** Knowledge and Experience Equivalent to a Civil Engineering Graduate with course work in hydrology, hydraulics, and soil mechanics plus at least 4 years of recent experience related to dams.	**Level 3 Reviewer:** Knowledge and Experience Equivalent to a Masters Degree in Civil Engineering with advanced courses in hydrology, hydraulics, soil mechanics, and rock mechanics, plus at least 6 years of recent experience related to dams and subsidence. Registration as a Professional Engineer is Recommended.
Advanced Complexity Plans (High- hazard potential dams; dams with complex conditions, such as upstream construction, mining near or under the dam or reservoir, etc.) It is recommended that reviews be obtained from Technical Support for plans in this category.	Not Advisable	Not Advisable without Level 3 Oversight	**Recommended Review Level**
Intermediate Complexity Plans (Plans involving the design of internal drains/filters; complex seepage analyses; decants buried under > 50 feet of cover; rigid spillway liners; dams on surface-mine spoil; minor modifications to high hazard potential dams)	Not Advisable	**Recommended Review Level**	
Lower Complexity Plans (Low hazard dams; plans with no upstream construction or underground mine workings; minor modifications to significant and low hazard potential dams)	**Recommended Review Level**		

Note: Persons with less experience can review the portions of plans for which they are qualified. For example, a less experienced person who had course work in open channel hydraulics could review the diversion ditch portion of an "advanced complexity" plan.

III. Impoundment Data Sheet

This sheet contains basic information relevant to impoundment plan requirements and will be helpful in conducting inspection activities by inspectors and impoundment specialists.

This sheet is completed for each construction stage, by the plan reviewer, at the completion of the review when the plan is recommended for approval, and should be forwarded to the district impoundment supervisor. The district impoundment supervisor will ensure that a copy is maintained in the impoundment file and a copy sent to the field office for insertion into the Uniform Mine File.

IMPOUNDMENT DATA SHEET

Completed by: _____ Date: _____

All Information Pertains to Construction Stage

Impoundment Name _____

Site ID No. _____

Hazard Potential Classification (Circle One) High Significant Low

CONFIGURATION

Maximum Crest Elevation _____ feet

Minimum Crest Width _____ feet

Minimum Required Freeboard from _____ to Crest is _____ feet

Decant Pipe — Material Type _____

Inside Diameter _____ inches

Inlet Elevation _____ feet

Open Channel (Emergency) Spillway — Elevation _____ feet

Bottom Width _____ feet

Lining Type _____

Embankment Slopes — Upstream _____

Downstream _____

Embankment Benches — Width _____ feet

Vertical Interval _____ feet

Groin Ditches — Lining Type _____

COMPACTION

Compaction Test Frequency _____

Moisture Content Range minus _____ % to plus _____ %

Compaction Density Standard _____ % Lift Thickness(es) _____ inches

INSTRUMENTATION

Piezometer No.	Maximum Allowable Water Elevation (feet)	Piezometer No.	Maximum Allowable Water Elevation (feet)

CRITICAL CONSTRUCTION ITEMS

_____

Flow Monitoring Location(s) _____

Number of Settlement Monitoring Devices _____

Frequency of Settlement Measures _____

Special Notes, Observations, and Other Instrumentation _____

IV. IRPI Data from Impoundment Plans

This form will be used by a plan reviewer to capture information from the impoundment plan that will be needed to complete some of the fields in the IRPI. The numbers provided in parenthesis on the form correlate to the fields in the IRPI Database. IRPI fields not captured from the plan review have been omitted on the form and will be compiled by district personnel. This form will assist District personnel in updating the IRPI. A form is needed for each stage of the plan being reviewed. The information should be consistent with the explanations for the IRPI fields contained in Appendix B. This form should be filled out by the plan reviewer at the completion of the review when the plan is recommended for approval, and should be forwarded to the district impoundment supervisor.

IRPI DATA FROM IMPOUNDMENT PLANS

Date _____ Completed by: _____

(2) State _____ (2) County _____

(3) Impoundment Name _____

(4) Impoundment ID No. _____

(8) All Information Pertains to Construction Stage

(9) Nearest Downstream City/Town _____ (10) Distance to Nearest City/Town (mi.) _____

(11) Latitude _____ (12) Longitude _____
(Degrees + (Minutes/60) + (Seconds/3600)) (Degrees + (Minutes/60) + (Seconds/3600))

(15) Stream impoundment is located on or tributary to: _____

(16) Section/Range/Township _____

(20) Company or consultant who prepared plan _____

(35) Foundation Type (rock; rock and soil; soil; unknown) _____

(37) Core Type (earth, plastic, etc.) _____

(38) Core Position (Upstream, Homogeneous, Core) U H C

(40) Type of Construction (Upstream, Downstream, Centerline) U D C

(41) Dam Crest Length _____ feet

(42) Structure Height (from downstream toe) _____ feet

(43) Open Channel Spillway Type Controlled Uncontrolled None

(44) Spillway Width at Maximum Discharge _____ feet

(45) Maximum Storage _____ acre-feet

(46) Normal Storage _____ acre-feet

(47) Maximum Discharge _____ cfs

(49) Drainage Area _____ square miles

(50) Surface Area _____ acres

(51) Decant Pipe Type _____

(52) Decant Pipe Diameter (ID) _____ inches

(54) Mining Underneath or Adjacent: Yes No

(55) Hazard Potential Classification High Significant Low

CHAPTER 8 – IMPOUNDMENT DESIGN GUIDELINES

The goal of MSHA's impoundment plan review and approval process is to ensure that plans are consistent with current, prudent engineering practice and will result in safe structures. This chapter provides guidance on the principal factors involved in the design and construction of impoundments. These guidelines are not intended to provide a comprehensive treatment of impoundment design and construction, but to provide guidance on recommended practices, sources of information, and the type of documentation and analyses that MSHA reviewers typically need to evaluate the adequacy of a submitted plan. Impoundment designs and construction specifications must be developed based on site-specific conditions and requirements. This can only be done by a competent and comprehensive engineering evaluation.

Plans submitted for approval should include all of the information required to explain and support the proposed design including narrative, design calculations, exploration logs, and test results. When computer programs are used for analyses, inclusion of program documentation and copies of the input and output files, in electronic format, is encouraged to facilitate the review process. In addition, plans should include a complete set of specifications and drawings in sufficient detail to clearly define the construction requirements. If conditions are discovered during construction that had not been anticipated in the design, or that do not permit the plan requirements to be implemented as intended, then the plan needs to be appropriately modified and the changes need to be submitted to MSHA for approval.

<u>The following topics are addressed in these guidelines:</u>

1. Hazard-Potential Classification
2. Impoundment Hydrologic Design Criteria
3. Probable Maximum Flood
4. Storm-Inflow Drawdown Criteria
5. Special Design Storm Considerations for Short-Term Conditions
6. Reservoir Flood Routing Analyses
7. Minimum Embankment Freeboard
8. Open-Channel Spillway Design and Erosion Protection
9. Reservoir Evacuation by Pumping
10. Decant Conduits – General
11. Design of Conduits for External Loading
12. Decant Conduit Installation (Backfill)
13. Controlling Seepage Along and Near Conduits
14. Pressure Testing of Spillway Conduits
15. Slope Stability Analyses
16. Seismic Stability and Deformation Analyses
17. Upstream Construction - Excess Pore-Water Pressure/Construction Procedures
18. Foundation Exploration
19. Foundation Preparation
20. Embankment Fill Placement and Compaction Specifications
21. Frequency of Testing to Verify Compliance with Compaction Specifications
22. Seepage and Phreatic Surface Level

23. Graded Filters
24. Use of Geotextiles as a Filter
25. Mine Workings Under or Near Dams and Impoundments
26. Construction Specifications
27. Construction Monitoring During Critical Phases of Construction
28. Instrumentation Monitoring of Impoundments
29. Fine Waste Disposal in Cells
30. Emergency Action Plans
31. Fines Recovery Operations
32. Provisions for Impoundment Abandonment

Updated design and construction criteria should be applied as the state-of-the-art for safe impoundments is advanced.

1. Hazard Potential Classification

It is common practice to classify dams according to the potential impact a dam failure would have on the downstream areas. "Federal Guidelines for Dam Safety: Hazard Potential Classification Systems for Dams," published in 1998, provides the classifications used by Federal agencies. Three hazard-potential classifications are used, as indicated below:

Low Hazard Potential: Dams assigned the low-hazard-potential classification are those where failure results in no probable loss of human life and low economic and/or environmental losses.

Significant Hazard Potential: Dams assigned the significant-hazard-potential classification are those dams where failure results in no probable loss of human life but can cause economic loss, environmental damage, or disruption of lifeline facilities.

High Hazard Potential: Dams assigned the high hazard potential classification are those where failure will probably cause loss of human life.

The main purpose of assigning a hazard potential classification to a dam is to ensure that appropriate design criteria are used in the dam's design. That is, more conservative design criteria are used as the potential for loss of life or property damage from failure of the dam increases. For example, more drilling and material property testing is normally performed for a dam with high-hazard potential than for one with low-hazard potential. And a dam with high-hazard potential would be designed to safely handle the probable maximum flood, while a low-hazard potential dam would be designed for a smaller storm, like the 100-year frequency rainfall.

Many of the impoundments that are under MSHA's jurisdiction have underground mining either underneath or near the dam or reservoir. This creates a situation where, in addition to the possibility of a release from an impoundment due to a dam failure, a release can also occur due to failure of the natural ground, or of man-made barriers, between the reservoir and the mine workings. If the reservoir breaks into the mine, not only would miners potentially be endangered, but the water or slurry can discharge out of the mine and potentially affect a

drainage area that is different from the one a dam failure would affect. To deal with this situation, MSHA takes the following approach:

a) The official "Hazard-Potential Classification" for the impoundment is based on the three classifications indicated above, and is assigned regardless of whether the potential hazard is from a failure of the dam or a failure into mine workings. This is the classification that is reported for the National Inventory of Dams.

b) For the purpose of selecting the appropriate design criteria for the dam, the hazard classification is based on the appropriate rating in the event of a failure of the dam itself. For example, an impoundment could have a high-hazard potential rating based solely on the potential for a failure into underground mine workings, with low consequences due to a failure of the dam itself. In such a case, the dam can be designed based on the low-hazard potential (e.g., the one-hundred year frequency design storm could be used), while the breakthrough evaluation and prevention measures, with respect to the extent of exploration, testing, monitoring, etc., would need to be appropriate for a high-hazard potential site.

2. Impoundment Design Storm Criteria

A dam needs to be able to safely accommodate the inflow from a storm event that is appropriate for the size of the impoundment and the hazard potential in the event of failure of the dam. Recommended minimum design storm criteria are summarized in Table I. Plans submitted to MSHA must show that during the design storm, sufficient freeboard will be provided, adequate factors of safety for embankment stability will be maintained, and significant erosion of discharge facilities will be prevented.

As indicated in Table I, dams with high-hazard potential, that is, sites located where failure of the dam would probably cause loss of life, should be designed to safely withstand the probable maximum flood (PMF). More details on the PMF are provided in item No. 3 below. Dams with significant hazard potential, that is, sites where failure of the dam would cause serious property damage or disruption of important facilities, should be designed for at least one-half of the PMF. Low-hazard potential dams should be designed to handle at least the 100-year frequency rainfall of 24-hour duration. Rainfall data is to be obtained from the most recent National Weather Service reports applicable to the area.

TABLE I - RECOMMENDED MINIMUM HYDROLOGIC DESIGN CRITERIA

HAZARD POTENTIAL (with respect to a hypothetical failure of the dam)		IMPOUNDMENT SIZE	
		< 1000 AF and < 40 feet deep	≥ 1000 AF or ≥ 40 feet deep
LOW Impoundments located where failure of the dam would result in no probable loss of human life and low economic and/or environmental losses.	Short Term	100-year rainfall	100-year rainfall
	Long Term	100-year rainfall	½ PMF
SIGNIFICANT / MODERATE Impoundments located where failure of the dam would result in no probable loss of human life but can cause economic loss, environmental damage, or disruption of lifeline facilities.	Short Term	100-year rainfall	½ PMF
	Long Term	½ PMF	PMF
HIGH Facilities located where failure of the dam will probably cause loss of human life.	Short Term	½ PMF	½ PMF
	Long Term	PMF	PMF

Notes

1. Impoundment size and hazard potential should be based on the total volume and depth of the impoundment including all water, sediment, and slurry that could be impounded.

2. Short-term criteria only apply to unavoidable conditions. The long-term criterion is to be met within two years of start-up. At abandonment, once the long-term criterion is no longer met, abandonment is to be completed within two years. Construction requirements are to be completed so that short-term storm criteria apply for one year or less. Construction must be scheduled and sufficient resources applied to minimize the time during which the short-term criterion applies and to make reasonably steady progress toward meeting the required criterion.

3. The ½-PMF design storm is based on one-half the inflow rates and volume from the PMF.

4. Impoundments located west of the 105th Meridian that require the PMF should also be evaluated for extreme thunderstorms and designed for the more critical condition.

5. Future downstream development may increase a site's hazard-potential rating and necessitate upgrading the structure to handle a design storm consistent with the new rating.

6. The appropriate design storm for determining freeboard and discharge requirements should be based on the hazard potential with respect to failure of the dam. For example, if an impoundment is rated as having "High-Hazard Potential" based solely on the potential for loss of life from a breakthrough into mine workings, but the hazard potential from a dam failure is lower, then the design storm can be based on the lower rating.

To determine the size and hazard potential for use in Table I, the volume and depth includes all water, sediment, and slurry that can be impounded. Note that the selection of the proper design storm from Table I is based on the consequences of a hypothetical failure of the dam itself. The ½-PMF design storm is based on one-half the inflow rates and volume from the PMF. Impoundments located west of the 105th Meridian that require the PMF for design purposes should be evaluated for extreme thunderstorms and designed for such storms whenever they are more critical.

Although flow through a decant system is normally insignificant during a flood routing analysis, a decant system with a properly designed trash rack and anti-vortex device, where appropriate, can be considered in a flood routing beginning with the pool level at the decant inlet at the start of the storm. Gated discharge facilities and pumps cannot be included in the discharge when routing a storm through the impoundment.

For impoundments whose outlet works and/or freeboard are designed to handle less than the PMF, plans must include information justifying such a decision. Documentation should include a detailed description and mapping of the downstream area which could be affected by a failure of the dam. If the hazard potential is not apparent, dam-breach analyses should be performed, and submitted with the plan, showing the flow depths and velocities at critical downstream locations. These analyses should consider the incremental impact of a dam failure under both normal and flood flow conditions (see "Federal Guidelines for Dam Safety: Selecting and Accommodating Inflow Design Floods," FEMA 94, 1998).

For impoundments located in series, where the failure of an upstream dam could contribute to failure of a downstream dam, assessment of the consequences of failure of the upstream dam must include the additional consequences of failure of any downstream dams. In such cases, the design storm for an upper impoundment must be equal to or greater than the design storm for the lower impoundment. Also, the design of a downstream impoundment must take into account the discharge from an upper impoundment, including a breach hydrograph, if appropriate, based on the design storm for the lower impoundment occurring over the entire contributing drainage area.

3. Probable Maximum Flood (PMF)

Current, prudent engineering practice requires that impoundments located where failure would probably cause loss of life be designed for the probable maximum flood (PMF). The PMF is defined as the maximum runoff condition resulting from the most severe combination of hydrologic and meteorological conditions that are considered reasonably possible for the drainage area.

Components of the PMF that must be determined by the designer for a particular site include: antecedent storm; principal storm; subsequent storm; time and spatial distribution of the rainfall and snowmelt; and runoff conditions. While there is basic agreement among dam safety authorities on the combination of conditions and events that comprise the PMF, there are differences in the individual components that are used. A reasonable set of conditions for the PMF appears to be the following:

- Antecedent Storm: 100-year frequency, 24-hour duration, with antecedent moisture condition II (AMC II), occurring 5 days prior to the principal storm.

- Principal Storm: Probable maximum precipitation (PMP), with AMC III. The principal storm rainfall must be distributed spatially and temporally to produce the most severe conditions with respect to impoundment freeboard and spillway discharge.

- Subsequent Storm: A subsequent storm is considered to be handled by meeting the "storm inflow drawdown criteria," which is discussed below.

PMP rainfall estimates for different areas of the U.S. can be found in reports prepared by the National Weather Service's Hydrometeorological Design Studies Center. For areas east of the 105th Meridian, estimates are given in Hydrometeorological Report No. 51. Recommended procedures for determining critical rainfall spatial and temporal distribution for areas east of the 105th Meridian are given in Hydrometeorological Report No. 52. The Corps of Engineers' computer program HMR52 can be used to compute precipitation values in accordance with the procedures given in Hydrometeorological Report No. 52, however, the program may not be applicable to all watersheds, particularly watersheds less than 10 square miles. For the region between the 103rd Meridian and the western continental divide, consult Hydrometeorological Report No. 55A. For areas farther west, Hydrometeorological Report Numbers 49, 57, 58, or 59 should be consulted. In addition to the PMP storm, impoundments located west of the 105th Meridian should be evaluated for extreme thunderstorms to determine which type of storm is more critical for design purposes.

As an alternative to using the PMF defined above, a design that follows the procedures used by a recognized dam safety authority will normally be accepted. However, designers are cautioned that storm criteria that are considered acceptable for dams with a properly designed open-channel spillway may not be appropriate where the runoff is to be stored. In storage situations, longer duration storms need to be considered as indicated in these guidelines.

4. <u>Storm Inflow Drawdown Criteria</u>

Impoundments must be capable of handling design storms that occur in close succession. To accomplish this, the discharge facilities must be able to discharge, within 10 days, at least 90 percent of the volume of water stored during the design storm above the allowable normal operating water level. The 10-day drawdown criterion begins at the time the water surface reaches the maximum elevation attainable from the design storm. Alternatively, plans can provide for sufficient reservoir capacity to store the runoff from two design storms, while specifying a means to evacuate the storage from both storms in a reasonable period of time – generally taken to be at a discharge rate that removes at least 90% of the second storm inflow volume within 30 days. When pumping is the sole means of drawdown, pumping should commence as soon as practical after the maximum allowable normal pool level has been exceeded. When storms are stored, the potential for an elevated saturation level to affect the stability of the embankment needs to be taken into account.

5. Special Design Storm Considerations for Short-Term Conditions

Recognizing that the mining industry is confronted with conditions that are unique to waste disposal operations, MSHA will consider accepting a design storm of less magnitude than the full design storm during unavoidable short-term construction periods. "Unavoidable" refers to periods of time when application of the full design storm criteria is virtually impossible. These periods are normally associated with initial start-up conditions and abandonment. Recommended design storms for short-term conditions are provided in Table I.

Examples of conditions where short-term criteria may apply are:

- Initial construction of a new impounding structure. The impoundment should be capable of accommodating the runoff from the short-term storm within one year and the long-term storm within two years.
- Changing from an open-channel spillway to handling the design storm by storage. The time period when the long-term design storm cannot be accommodated should be kept as short as possible, and a comprehensive plan and schedule for the sequence of the change should be provided.
- Abandonment by elimination of impounding capability. The impounding capability of the facility should be eliminated within 2 years after the impoundment can no longer accommodate the long-term design storm. Additionally, the abandonment should be phased so that the facility is capable of accommodating less than the short-term storm for no more than one year.

During any periods for which the long-term design storm cannot be accommodated, reasonably steady progress must be made toward either meeting the long-term criterion or eliminating the impounding capability of the site. In all cases, short-term criteria should be kept to the shortest time possible. A smaller storm should never be used in a design just for convenience or just to reduce the final cost of an impoundment.

6. Reservoir Flood Routing Analyses

Plans should include detailed hydrologic and hydraulic analyses used in determining the maximum pool level which will occur, and the required size of discharge facilities, when the runoff from the design storm is routed through, and/or stored in, the impoundment. Details that need to be provided for each stage include: the stage-storage relationship for the reservoir; the hydrologic analyses of the runoff, inflow and outflow hydrographs; the stage-discharge curves for discharge facilities; and the storm- routing analysis. When a plan includes upstream construction, the reservoir elevation-storage relationship needs to take into account the reduction in reservoir area and storage from the upstream fill placement. While storm routings are performed starting with the pool level at the spillway or decant inlet, for slurry impoundments the pool should normally be kept far enough below the level of the spillway or decant to prevent smaller storms from causing a discharge of sediment or black water.

Suitably scaled topographic maps of the entire watershed area and the reservoir area, and all supporting calculations, need to be provided in the plan. When computer programs are used for analyses, inclusion of program documentation, and input and output files in electronic format, is encouraged to facilitate the review process.

7. Minimum Embankment Freeboard

The design freeboard is the vertical distance between the lowest point on the crest of the embankment and the maximum water surface elevation resulting from the design storm. Freeboard provides a margin of safety against the embankment being overtopped from wave run-up, and allows for uncertainty in estimates of such items as runoff and embankment settlement. The crest of an embankment should be overbuilt or cambered during construction with enough extra height provided to ensure that the intended freeboard will not be diminished by embankment or foundation settlement.

Sufficient documentation should be provided in impoundment plans to verify the adequacy of the freeboard. Items that should be considered in determining freeboard requirements include: frequency of the design storm, duration of high water level, effective wind fetch, water depth, potential wave run-up on the upstream slope, ability of the embankment to resist erosion, potential for embankment/foundation settlement, and potential for mine subsidence. Without documentation, and absent unusual conditions, a minimum freeboard of 3 feet is generally accepted for impoundments with a fetch of less than 1 mile. Where needed to prevent erosion from wave action, measures such as riprap should be provided on the upstream slope. A useful reference on wave run-up is the Corps of Engineers' Coastal Engineering Manual (2003).

Since the crest elevation of a slurry impoundment can change frequently, to help ensure that adequate freeboard is maintained, slurry impoundment plans should include a graph or table that shows the maximum allowable normal pool level, and the allowable spillway and decant inlet elevations, for given crest elevations. In determining allowable levels, the volume occupied by settled fines above the pool or outlet level needs to be taken into account.

8. Open-Channel Spillway Design and Erosion Protection

Spillways must be designed to safely discharge storm outflow to a point far enough downstream where the embankment will not be endangered by erosion. The serious consequences of spillway failure dictate that conservative methods are applied to their design. Plans need to include detailed analyses showing that 1) the maximum design flow will be contained in all portions of the spillway channel with adequate freeboard; 2) the spillway can withstand the design flow velocities without significant damage; and 3) the durability of spillway materials is adequate for their required design life.

To show that spillways are adequate, submitted plans need to include a hydraulic analysis for each spillway showing the maximum flow depths and velocities, the minimum channel freeboard, the duration of flows, and a complete water-surface profile. Plans also need to provide substantiation that the minimum freeboard in the spillway channel is adequate. For example, for supercritical flow conditions, "Design of Small Dams" (1987) provides this

empirical relationship for desirable freeboard: Freeboard (in feet) = $2.0 + 0.025(v)(d)^{.33}$, where (v) is the flow velocity in feet per second and (d) is the flow depth in feet. In addition, analyses need to show that sufficient channel depth is provided to contain the increased flow depths along the outside of channel bends, at contractions in the channel, and at hydraulic-jump locations.

A significant concern with spillways is their ability to resist erosion. Preferably, spillways are cut into rock resistant to weathering and erosion. Otherwise, a lining must be provided capable of resisting the erosive forces for the maximum spillway discharge. Where linings are proposed, maximum discharge conditions need to be analyzed to determine the magnitude of the forces (e.g., hydrodynamic lift and drag, tractive and critical shear stress, hydrostatic pressure) that could be exerted on the lining. The plan should include a technical analysis demonstrating that the lining will have adequate factors of safety against the maximum hydraulic and hydrostatic forces.

Plans must include detailed specifications and drawings on liner material and placement, including anchorage measures. Items addressed should include:

- The integrity of the spillway foundation. The design should include comprehensive specifications for foundation preparation and any filter layers needed to prevent underlying material from washing out.
- The integrity and durability of the liner itself. Damage is most likely to occur during high outflow conditions when there is not access for making repairs.
- Liner anchorage and under-drainage. Measures to control and resist uplift and tractive forces for the maximum spillway discharge and uplift pressures.
- Potential for erosion at transition areas upstream and downstream of the liner, and protection or anchorage of liner edges.
- Provisions for energy dissipation. Measures such as stilling basins should be provided as appropriate.
- The potential effect of debris impingement and displacement of a portion of the liner. Where damage from floating debris may occur, measures such as trash booms should be used to prevent debris from entering the spillway. Trees or rock which could fall and damage the liner should be removed.
- Detailed specifications for liner installation and minimum liner material requirements.
- Detailed drawings illustrating the location of the liner and construction details.
- Provisions to have the liner installation monitored by an engineer familiar with the design requirements. If unanticipated conditions are found during liner installation, a change in the design and/or specifications may be needed and a modification to the plan would need to be approved.

As indicated above, the preferred design of an open channel is to cut it through competent rock, that is, rock which is free of significant geologic discontinuities and rock of sufficient strength and durability to resist design flow velocities and weathering over the life of the spillway. Subsurface exploration should be conducted to adequately define the type and condition of rock at critical cross-sections along the channel alignment. The subsurface exploration needs to be fully documented in the submitted plan, along with details and data on the rock property testing. Plans should require that the rock in spillway channels be examined by an engineer or geologist to verify its suitability.

When a spillway cannot be cut through competent rock, a non-erodible spillway lining needs to be provided. Materials that have been used to provide erosion protection in impoundment spillways are discussed below.

Riprap has been used as channel lining material; however, its stability under steep grades or high flow velocities is a serious concern. The various design methods that are available will yield a wide range of required rock sizes for a given set of conditions. Most riprap design methods were developed by Federal and State agencies for public works projects such as bridge abutments, flood channels, and canals. Failure of riprap protection in these projects generally will not have consequences as serious as the failure of a riprap lining in an emergency spillway, which could cause a dam breach. Therefore, the use of riprap in emergency spillways subject to high velocities is discouraged, unless a detailed technical justification, covering all potential failure modes, is provided. Where riprap is proposed, a conservative design method should be applied and plans must include calculations to support the proposed stone sizes. The rock should be angular in shape having no dimension larger than three times the smaller dimension. Riprap specifications should address stone gradation and unit weight, layer thickness, stone durability, bedding requirements, filter/erosion protection for underlying material, stone placement procedures, and construction monitoring.

Gabions, which consist of wire baskets filled with rock, are considered to solve some of the problems related to the use of riprap. Properly designed, the wire mesh can successfully contain the rock when exposed to high velocity flow. Information submitted for the use of these products should include the wire-mesh manufacturer, foundation material and preparation, rock size-distribution, rock durability, anchoring methods, calculations demonstrating stability for the design discharge and duration, and evaluation of the expected useful life of the wire mesh. Manufacturer's recommendations, as they apply to spillway applications, should be followed.

Rigid linings are a potential solution to the limitations associated with the use of riprap. Rigid linings include reinforced concrete, grouted riprap, and some fabric-formed concrete products. Rigid linings can be destroyed due to flow undercutting the lining, channel head-cutting, or hydrostatic pressure behind channel sidewalls or under the liner. If a section of a rigid lining fails, then the remaining sections could fail in a rapid succession. Positive under-seepage cutoffs and weep holes are design measures that should therefore be used. If grouted riprap is proposed, the specified layer thickness needs to be appropriate for the flow velocity and the depth of grout penetration and the methods to be used to ensure adequate grout penetration need to be specified.

Formed concrete products can be cast-in-place or pre-cast. These products may be un-reinforced or may contain various types of reinforcement. Regardless of the type of product used, the concrete or grout has to be appropriately designed, proportioned and produced for the strength and durability requirements of the application. The concrete/grout must be capable of withstanding the erosion and tractive forces associated with water flow, as well as freeze-thaw and wet-dry durability for the site specific climate. Cast-in-place products typically consist of fabric bags, and may consist of individual units or mats that are filled with concrete or grout. Pre-cast products may consist of individual blocks or articulated mats that are individual blocks connected by cables. The blocks can be simple geometry or may be designed to interlock and

provide resistance to shifting or displacement from tractive forces. Articulated mats may be cast-in-place or pre-cast and set in place, and have the ability to flex and conform to the surface profile, as well as to deform with settlement. Reinforcement for cast-in-place or pre-cast products may consist of traditional rebar, wire mesh, or cable. Fiber reinforcement mixed with the concrete/grout should not be used for concrete or grout subjected to water flow.

The use of plastic liners has been proposed as spillway erosion protection. Plans proposing the use of plastic liners need to address all pertinent design issues including: hydraulic and uplift forces; liner installation procedures; foundation material and drainage; liner anchorage; protection of liner edges; material durability; and protection from puncture damage from animals (e.g., deer) or equipment traveling on the liner. Manufacturer's recommendations, as they apply to spillway applications, should be followed.

Linings consisting of synthetic grass-reinforcement materials have been used in the spillways of some impoundments where the design flow velocities and durations are low. Typically, such linings are used on low-hazard potential structures.

The selection of the type of lining is critical to the overall facility design. Seeking design support from the manufacturer in making this decision is important. Manufacturers should be made thoroughly aware of the intended use of their product and the consequence of system failure, and, as a minimum, the applicable manufacturers' installation recommendations should be followed.

A significant consideration with any spillway, whether cut into rock or lined, is periodic examination. Exposure to the elements will cause deterioration to occur and routine evaluation of any deterioration and its potential impact on spillway performance is critical. Impoundment plans should address spillway examination requirements.

A diversion ditch can be considered to reduce an impoundment's drainage area only if the diversion ditch has been designed to carry no less than the design storm for the impounding structure and is designed, constructed, and maintained to standards no less than that of an open-channel spillway. Diversion ditches which are only designed to reduce the inflow from smaller intensity storms can not be used for flood routing.

Groin ditches, used to collect runoff from the dam and the adjacent hillside, should be designed for at least a 100-year frequency storm where significant erosion could damage the dam. It is prudent to specify a freeboard of at least $1.0' + 0.025v(d)^{.33}$ for supercritical flow conditions in the design of groin ditches.

9. Reservoir Evacuation by Pumping

The best practice is to provide a positive, gravity-initiated means of discharging stored storm runoff. However, the use of pumps has been proposed in some plans and their use is evaluated on a case-by-case basis. A pump system may not be used to route storm runoff through an impoundment. If a pump system is the primary evacuation strategy, the system must have sufficient capacity to meet the storm inflow drawdown criteria discussed elsewhere in these guidelines, and the system must be operated such that it essentially serves the same function as a decant outlet (that is, drains water from the impoundment when storm inflow raises the pool above the allowable normal level).

Plans proposing pumps must include all pertinent design information and address issues involving capacity, power source, and maintenance of the proposed pump installation. Plans should include calculations substantiating that the pump(s) can discharge the stored runoff within the allowable time. Information on pump locations and the immediate availability of a backup pump(s), in case the primary pump(s) fails, should be provided. The specifications should indicate the system requirements, and design drawings should illustrate the location(s) and details of the pump(s). The specifications should also indicate that the pumps will be operated as necessary to draw down the pool to the normal allowable pool level.

Upon initial installation, pumps should be operated for a sufficient length of time to ensure proper operation of the system. The plan should include the requirement that the pump system be activated at least monthly thereafter to ensure it is ready for use. Since power lines and electrical auxiliary power sources may become damaged during a storm, the only acceptable power source for a pump is an internal combustion engine, either coupled to the pump or as an adjacent generator specifically for the pump. The method of storage for the pump's fuel supply, as well as enclosure or storage of the pump and the generator /combustion engine, should be provided in the plan. Pump discharge must be handled in a manner to prevent damage to the dam from erosion.

10. Decant conduits – General

Design items to be addressed for decant conduits include: hydraulic capacity (head versus discharge analysis); strength and deflection; durability; corrosion protection; joint details; joint water-tightness; riser structural stability; riser-transport section connection; thrust blocks at changes of flow direction; resistance to floatation forces; differential settlement; bedding and backfill; seepage control; erosion control at the outlet; energy dissipation; trash guarding; construction monitoring, and where appropriate, pressure testing and anti-vortex devices.

Conduits should be provided with an appropriate trash guard to prevent inlets from becoming clogged with debris. Trash-racks should be designed considering the nature of the debris to be intercepted, the size of the conduit, and the accessibility of the guard for cleaning. The flow area is normally fixed by a limiting velocity through the guard. “Design of Small Dams” recommends that for trash-racks inaccessible for cleaning, the velocity through the rack openings should not exceed 2 feet per second. A velocity of up to 5 feet per second may be tolerated for racks that are accessible for cleaning.

Other general points concerning decants include:

- Plans should address corrosion protection on both the inside and outside surfaces of steel pipes. Details of corrosion potential and protection measures should be provided with provisions to repair any damage that occurs during pipe installation.
- Valves should never be placed at the downstream end of conduits because the conduit could be pressurized to the full reservoir head when the valve is closed.
- Conduits which are damaged to the point where their structural integrity may be affected should not be installed or re-installed.
- Conduits that are not totally located on unyielding bedrock need to be designed so that the amount of predicted foundation settlement does not damage the conduit or cause separation of joints.
- Decant designs should consider and account for the potential for differential settlement at the joint where a conduit connects to a riser structure.
- Conduits constructed on a yielding foundation should be cambered to accommodate the predicted foundation settlement, to achieve a proper final grade.
- Where significant changes in the horizontal or vertical alignment of a conduit occur, plans should include the calculations and construction specifications for the placement of thrust blocks. A conservative estimate of the allowable bearing load should be made for the soil supporting the thrust block.
- If a decant pipe outlets into a groin ditch, the groin ditch is considered to be part of the spillway system. In this case, the groin ditch should be designed to handle the adjacent hillside runoff and provide an outlet channel for decant discharge such that erosion which could jeopardize the safety of the dam is prevented in the event of the impoundment design storm.
- If the end of a conduit is cantilevered, flow through a conduit can cause the end of the conduit to vibrate. Such vibrations have been suspected of contributing to dam failures by leading to seepage problems at the conduit/backfill interface. To prevent this problem, the end of a decant conduit should be fixed to the extent necessary to prevent flow from inducing vibrations in the conduit.

A reference for conduits is "Conduits through Embankment Dams: Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance and Repair," FEMA, 2005.

11. Design of Conduits for External Loading

When a conduit is to be installed under or through an embankment, plans must demonstrate through analyses and calculations that adequate factors of safety are provided against the various potential structural failure modes. This applies for decant conduits, as well as collection and outlet pipes installed in internal drains. Potential structural failures include wall crushing, wall buckling, and excessive deflection or wall strain. Parameters used in the analyses must be adequately substantiated in the plan.
The recommendations contained in the literature of conduit manufacturers, such as tables for the allowable cover over a conduit, must be used with caution because the information may not be

directly applicable to impoundments. Applicable manufacturers' recommendations should be met, but manufacturers' tables should be used for preliminary design purposes only. Detailed analyses and calculations need to be included in the plan.

Designers and plan reviewers should note that technical literature contains significant differences of opinion concerning the structural design for flexible conduits. Particular points of contention concern the calculation of deflection and values of the modulus of soil reaction. For these reasons, the applicability of a manufacturer's recommended design procedure needs to be verified for the particular conditions found at a site. This is especially true for deep burial situations, as the emphasis for most products has been on relatively shallow cover conditions, such as sewer installations. Until performance data is established for high cover situations, conservative design methods need to be used. Factors of safety of at least 2.0 should be specified. Where applicable, deflections should be checked using the Iowa Formula, with conservative values for the modulus of soil reaction (Spangler, 1982; Howard, 1977). Because of the limitations of traditional, empirical design methods, use of a finite-element analysis is considered by some to represent the best available method of design. For flexible conduits, in addition to the deflection caused by fill loading, installation deflection also needs to be taken into account in determining whether total deflection will be within acceptable limits. Consideration should be given to limiting fill height by installing new conduits at higher elevations and grouting deeper buried conduits.

In high fill applications, due to uncertainty about pipe/soil interaction and the lack of performance data, the performance of the pipe needs to be verified by monitoring the pipe's deflection. Initial measurements should be taken shortly after installation and then at pre-determined intervals based on depth of cover. Various methods, such as deflectometers, sonar and laser devices, and closed-circuit TV cameras, have been used for this purpose. Based on these measurements, parameters affecting deflection can be back-analyzed and the likely future pipe deflection, and the point at which remedial actions may be required, can be better modeled and estimated. Contingency measures to repair or replace the conduit are required to establish the actions to be taken in the event that monitoring shows that structural performance limits are being approached.
Plans should take into account the potential for decant deflection problems at risers that are abandoned, capped, and buried. The additional loading on a capped riser as it becomes buried, combined with drag forces, causes an increase in the localized downward forces applied to the transport section of the conduit at the riser junction. Plans should include an evaluation of this condition and appropriate design provisions.

The "imperfect ditch" or "induced trench" method of conduit installation should not be used in dams due to the potential for creating a seepage path and the uncertainty of the arching action under saturated conditions. Backfill and bedding materials must be selected and installed to provide adequate structural support and to control seepage.

Collection and outlet pipes installed in internal drains should be designed to withstand overburden pressures and construction loadings, such as heavy equipment. Single wall plastic pipes, distributed on a spool, have been found to be prone to collapse in these applications, possibly from damage that occurred during construction. Use of rigid tubes, such as double-wall

plastic pipes, is recommended for such applications, using fittings for changes in alignment. Plans should include an evaluation of the ability of the specified pipe to function as intended under the design fill height. The minimum amount of fill to be placed over the pipe to prevent damage from heavy equipment traveling overtop of the pipe should be specified.

12. Decant Conduit Installation (Backfill)

Installation of a decant conduit is a critical phase of construction because the conduit and its backfill provide a potential path for excessive seepage and internal erosion, and because of the importance of the structural integrity of the conduit to the safety of the dam. Plans must provide detailed specifications on how conduits will be installed to ensure that proper bedding and backfill material is used, the materials are adequately compacted around the conduit, and appropriate provisions for handling seepage are provided.

An area of particular concern is compaction of backfill in the haunch area of conduits, that is, in the area from the bottom of the pipe to its springline (horizontal diameter). Conduit design and construction is addressed in the Federal Emergency Management Agency's (FEMA) sponsored publication "Conduits through Embankment Dams: Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, and Repair" (scheduled for publication in 2005). This publication addresses the difficulties of achieving adequate compaction in the haunch area and recommends as "best practice" the use of conduits shaped to eliminate the haunch area with the sides of the conduit battered through the impervious zone to allow rubber-tired equipment to compact the backfill directly against the conduit.
The minimum requirements for the installation and backfilling of conduits should be included in the specifications section of the plan. Key points to be addressed concerning conduit backfilling include:

- Plans need to specify detailed procedures and sequences for the steps to be used to install and backfill the conduit. This should include the type of compaction equipment to be used.
- In particular, the installation procedure should indicate, especially for the haunch area, how the installation will achieve full contact between the conduit and the bedding and backfill, and how the specified bedding and backfill densities will be attained and verified.
- Backfilling procedures should recognize that it is not generally possible to achieve full contact and adequate compaction in haunch areas without special construction measures, such as shaping the bedding to fit at least the bottom one-third of the conduit. (An alternative is to encase the conduit in adequately reinforced concrete which is shaped with battered sides to allow compaction with rubber-tired equipment. A particular concern with such a conduit would be that it be placed on an unyielding foundation or be analyzed for its ability to withstand potential differential foundation settlement.)
- A conduit constructed by encasing a pipe in concrete should be designed for the loading appropriate for a rigid conduit.
- If a technique such as shaping the bedding to conform to the bottom portion of the pipe is used, a small amount of fine sealing material, such as bentonite slurry or powder, should

be used, if necessary, to fill in small irregularities and help ensure full contact between the pipe and the prepared bedding surface.

- When backfill is compacted with hand-operated compaction equipment, thin layers must be used to achieve a sufficient degree of compaction. Lifts of no more than 4 to 6 inches, consistent with the capability of the compaction equipment, should be specified.
- Field tests to ensure that specified densities and moisture contents are met should be conducted for every 200 cubic yards of backfill (more frequently for smaller diameter pipes where the total volume of backfill is small), and anytime compaction is suspect or there is difficulty in obtaining compaction.
- Care should be taken in handling and placing backfill to minimize segregation. For example, larger particles will tend to accumulate at the bottom edge of a dumped pile of material.
- A maximum backfill particle size should be specified to prevent point loadings on the conduit.
- Backfill should be kept at about the same elevation on each side of the conduit during the installation process.
- Measures should be taken, such as holding down the conduit, if necessary, to prevent the conduit from lifting during the backfilling process.
- Trench walls should be flattened enough in the impervious zone to allow bonding of compacted fill to the trench sidewall and to minimize differential settlement.
- If flowable fill (also referred to as "controlled low strength material") is proposed as pipe backfill, design issues dealing with the material's strength and deformation properties need to be addressed. When used with flexible pipes, flowable fill needs to be designed so that it will deform like a well-compacted granular backfill. If the fill is too strong, it will be subject to cracking, and stress concentrations may occur between the flexible pipe and the more rigid backfill. Designers should note that the properties of cement-based materials vary depending on the particular constituents used to formulate the fill. Testing should be performed on samples of the specific materials and mixture proportions that are to be used, to demonstrate that the properties of the proposed flowable fill are appropriate for the conditions.
- The increase in strength that will occur over time with a cement-based flowable fill needs to be taken into account. A fill that gains too much strength will not deform with the pipe and will result in stress concentrations. The rate at which the fill gains strength is greater at early ages, but gains can continue for virtually the life of the material. The time frame for the major portion of the strength increase will range from a few months to several months depending on the characteristics of the cementitious materials. When pozzolanas such as fly ash are used, the major portion of the increase may occur over several months. Testing needs to be performed to show how strength increases over time.
- Another issue with flowable fill is shrinkage and thermal contraction. Cement-based materials will normally shrink over time. This can be due to moisture loss, especially where the fill contains high water content, or may be a characteristic of the materials used. Furthermore, due to the heat of hydration created by the reaction of cement, the fill will be in an expanded thermal state when it sets. The fill will subsequently cool and contract. The potential for the fill to shrink and pull away from the pipe or trench walls, creating seepage paths, needs to be taken into account in the design.

- If a pipe is encased in grout or concrete, the pipe needs to be designed to withstand the hydrostatic pressure that can develop at the outside surface of the pipe due to water that gains access through joints or cracks in the encasement, or seepage through the encasement material. Otherwise, the pipe can collapse inside the encasement. The full hydrostatic pressure from the reservoir should be considered.
- Buried conduits can be damaged if heavy equipment passes over them before a sufficient amount of fill has been placed over the conduit. Plans should specify the minimum amount of fill to be placed above conduits (decants and drain pipes) before it is safe for trucks or heavy equipment to travel over them.

Plans should require that an engineer who is familiar with the plan requirements, preferably a representative of the designer, monitor the conduit installation process. This is to ensure that the conduit is installed according to the specifications, the materials are consistent with the design intent, the workmanship is adequate, and any necessary changes in the installation materials or procedures are submitted for approval before being implemented. The engineer should be required to inspect and accept the conduit bedding and backfill before the embankment fill is placed over the conduit.

13. Controlling Seepage Along and Near Conduits

Designers have long recognized that conduit installations provide an opportunity for seepage along the conduit, or through the backfill. Seepage through this zone, if uncontrolled, can cause internal erosion and has been identified as the cause of embankment failure in many cases. In current practice, this problem is normally handled through the installation of a seepage diaphragm.

A seepage diaphragm consists of a zone of granular drainage material, protected by a filter layer, which is placed around the conduit to serve two functions. One function is to collect the water that seeps through the conduit backfill and along the conduit/backfill interface, and discharge this water under controlled conditions. The second function is to intercept cracks that may form in the backfill. Cracks may result from differential movement (caused by arching or differences in the compressibility of the backfill versus adjacent fill areas) and/or by hydraulic fracturing (caused by the pressure of the seeping water exceeding the confining stress in the backfill). The seepage diaphragm, being constructed of free-draining material that will not sustain a crack, intercepts such cracks, and, provided appropriate filter layers are incorporated, prevents the loss of material by piping or internal erosion.

Useful guidance on diaphragm design is provided in the NRCS's Technical Note 709, Dimensioning of Filter-Drainage Diaphragms or Conduits According to TR-60 (1985), with a supplement dated 1989. In general, diaphragms are located in the downstream portion of the embankment and are recommended to project out from the conduit for a distance of two to three times the conduit's diameter. However, designers should extend the dimensions of diaphragms farther if necessary to intercept any portions of the conduit backfill likely to be affected by differential settlement. An example would be if an installation trench extended outside the two to three diameter guidelines. A minimum seepage diaphragm thickness of 3 feet is proposed by the NRCS guidance, but, unless strict construction control is provided, thicker diaphragms are

recommended to avoid contamination and for ease of construction. A drain must be provided from a seepage diaphragm either by tying it into the embankment's internal drainage system, or by providing a separate drain, preferably by running a filter/drain backfill envelope continuously along the conduit to where it exits the embankment. A separate drain has the benefit of allowing the amount of conduit-related seepage to be monitored separately.

Plans should include complete details on seepage diaphragm installations including the material specifications for the drainage and filter zones, the dimensions and location of the diaphragm, and the provisions for outlet drains. Plans should require that the seepage diaphragm be accepted by an engineer who is familiar with the design requirements before the diaphragm is covered.

Before the concept of seepage diaphragms was developed, the method commonly used to attempt to control seepage along a conduit was to install anti-seepage collars. These collars, constructed of an impermeable material that attached to and extending out from the conduit, increased the length of the seepage path along the conduit. Seepage collars have been found to be ineffective in preventing many failures associated with conduits. Drawbacks include the difficulty of compacting around them, their inability to prevent flow through cracks in the backfill farther away from the pipe, and their tendency to pull apart pipe installed on a spreading foundation. As the sole means of controlling seepage along a pipe, anti-seepage collars are normally only considered suitable for small, low-hazard-potential impoundments. Where anti-seepage collars are proposed, they should increase the seepage path along the pipe by at least 15 percent, have a connection to the pipe which will remain watertight during potential pipe deflection, and not create an excessive stress concentration in the pipe wall.

14. Pressure Testing of Spillway Conduits

Conduit joints should be designed and constructed to remain watertight under maximum anticipated hydrostatic head. Problems with both infiltration and exfiltration have been observed in impoundment conduits. As a result, MSHA requires pressure testing of all pressure conduit spillways. Joint tightness also should be tested in non-pressure situations where conditions are such that loss of backfill or slurry could occur due to infiltration or leakage along the conduit. The minimum requirements for pressure testing should be included in the specification section of the plan. The plan should also explain the basis or reference for the procedures to be used.

For specifics on pressure testing procedures, designers should consult the recommendations of conduit manufacturers and organizations such as the American Water Works Association and the NRCS (see for example the National Engineering Handbook, Part 642, Specifications for Construction Contracts). Allowable rates for "apparent leakage" apply in some situations to account for factors such as water absorption or conduit expansion, but any leaks that occur during pressure testing need to be repaired and the pipe re-tested.

Factors to consider related to pressure testing include:

- Test pressures are commonly specified at a value greater than the maximum pressure that will develop in the conduit, such as 120 percent of the maximum pressure.

- The test period should range from 2 to 24 hours depending on conduit material and jointing.
- Joints should be visually inspected for leakage.
- Manufacturer's recommendations should be followed, as far as they apply to dam applications, with respect to test duration and leakage allowances.
- Conduits are normally pressure tested prior to backfilling so that any leaks can be readily repaired. Designers should consider, however, that joints might not remain watertight after the pipe has been buried under fill and deflection and/or settlement occurs especially for pipes with mechanical couplings. Plans should address this concern.
- All installations should be equipped with a pressure gauge and pressure relief valve during the test procedure, and appropriate safety precautions should be taken. Performing the test with pressurized water, versus pressurized air, is recommended for safety reasons. Pressurized air contains stored energy which can be released explosively should a failure occur.
- The conduit and end plugs should be sufficiently braced and anchored against movement during the testing.
- Internal and external temperatures should be monitored to provide pressure/temperature data in the event calculations become necessary.
- Where welded pipe is used, the welder should be certified for the specific type of welds to be performed.

For non-pressure applications using corrugated metal pipe (CMP), hugger bands with gaskets should be used as a minimum; dimple bands are not acceptable. Furthermore, all corrugated metal pipe should be the welded seam type; lock seam and riveted CMP are not acceptable unless adequate leakage control measures are provided. The use of CMP is typically only considered suitable for small dams with low-hazard potential.

While the watertightness of joints is a definite concern in pressure flow situations, joint tightness may also be a concern in non-pressure flow cases. This occurs when the backfill around a conduit is potentially erodible material, such as a fine sand or silt, which would tend either to infiltrate the conduit or to be washed out by exfiltration of water from the conduit. The former situation is a particular concern when settled slurry, which forms the foundation for an upstream construction stage, can potentially infiltrate a conduit. When conditions are such that infiltration or exfiltration could affect the safety of the dam, plans should include (even in non-pressure flow designs) a minimum pressure testing requirement. Testing joints to a nominal pressure will provide some assurance that the joints were properly constructed, will be soil tight, and will not allow significant leakage.

15. Slope Stability Analyses

Provided sufficient design data has been obtained, the stability of an impounding structure should normally have minimum static and seismic factors of safety of at least 1.5 and 1.2, respectively, under maximum anticipated pore-water pressure conditions. When few tests are made, or test results are widely scattered, either conservative values of shear strength should be used, or higher factors of safety provided. The most critical or worst-case slope conditions need to be analyzed. A sufficient number of failure surfaces must be analyzed to show that the

minimum factor of safety has been bracketed. Where conditions warrant, both circular and irregular or wedge-shaped failure surfaces should be investigated, as well as both upstream and downstream slopes. In addition to evaluating long-term conditions, stability should also be evaluated at intermediate stages, at end-of-construction, and for rapid drawdown, whenever such conditions may be critical. The minimum acceptable factor of safety for end-of-construction and rapid drawdown conditions is normally 1.3. A useful reference on slope stability issues is the Corps of Engineers' publication "Slope Stability" (2003).

Sufficient subsurface exploration and material testing must be conducted to adequately define the geometry, materials, and properties in critical stability cross-sections. The subsurface exploration must be fully documented in the submitted plan, along with complete details and data on all material-property testing. The shear strength of fill materials should normally be based on samples compacted at the highest water content and lowest density consistent with the specifications. The basis for phreatic surfaces used in the stability analyses must be fully documented in the plan. When computer programs are used in stability analyses, inclusion of the input and output files in electronic format is encouraged to facilitate the review process.

16. Seismic Stability and Deformation Analyses

Dams must be designed to be stable under all loading conditions, including the ground motions resulting from a design earthquake appropriate to the location, size and hazard-potential rating of the site. Seismic stability evaluations fall into two categories:

- If there are no materials in the embankment or its foundation that are subject to significant strength loss as a result of shaking, then a "pseudo-static" analysis is generally acceptable. In a pseudo-static analysis, the impact of an earthquake is usually modeled by applying an additional static force based on an appropriate seismic coefficient. A factor of safety of at least 1.2 should be provided.

- If the potential for strength loss or the development of elevated pore-water pressures exists as a result of seismic loading, then a more rigorous evaluation is needed. In this case, both the stability of the embankment must be analyzed and the amount of embankment deformation or settlement that may occur must be evaluated. Lower factors of safety may be acceptable depending on the conservatism of the analysis and such factors as the location of the critical failure surfaces within the embankment cross-section – that is, if a portion of the embankment became unstable, would a sufficient section of the crest remain intact to prevent a release from the impoundment. In addition to stability concerns, sufficient freeboard would need to be provided to compensate for the maximum amount of crest settlement that may occur.

The potential for shaking to cause strength loss or elevated pore-water pressures is especially critical for slurry impoundments constructed using the upstream construction method, where the embankment is raised by building over settled fines; and for any site where there may be a zone of fines or other loose, saturated sandy or silty material within the dam or its foundation. When subjected to shaking, loose or hydraulically placed materials exhibit a contractive response if unsaturated, and if saturated, high pore-water pressures can be induced. This can cause

liquefaction, or a rapid loss in shear strength. Liquefaction, or a rise in pore-water pressures if liquefaction does not occur, can cause failure or overtopping of a dam by causing the slopes to become unstable or the crest to slump. During the 1971 San Fernando earthquake, for example, the Lower San Fernando Dam, which was a hydraulic fill embankment, came within 5 feet of breaching when the upstream slope slid into the reservoir and the crest settled 30 feet. Besides slope failure or overtopping, large earthquake-induced settlements of a dam can cause cracking that may lead to failure from internal erosion.

Sites potentially subject to liquefaction and seismic deformation involve technical issues that are far too complex to address in detail in "design guidelines" such as these. Such sites should only be designed by engineers knowledgeable and experienced in the fields of soil dynamics, liquefaction, and earthquake engineering. The state-of-practice of seismic evaluation of dams continues to progress and designers should consult the publications of dam safety organizations such as the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation for the latest methods and practices.

For high-hazard potential impoundments with the potential for liquefaction or elevated pore pressures to affect stability, seismic analyses should be evaluated considering the maximum credible earthquake (MCE) that can affect the site. The MCE would cause the most severe ground motion capable of being produced at the site based on the currently known tectonic framework and seismological data. In determining ground motions for use in design, potential seismic events occurring both near and farther from the site need to be considered to determine the combination of acceleration and frequency content that is most critical to the embankment. For preliminary analyses, the ground motions used on other projects in the area, such as seismic studies on Corps of Engineers' dams, could be reviewed. For the final design on critical structures, consultation with an engineering seismologist, familiar with local seismology, is recommended.

Seismic evaluations normally progress from simplified to more complex analyses as needed to demonstrate that the design provides an adequate margin of safety with respect to slope stability and deformation. In the most simplified case, seismic stability is evaluated by assuming that potentially liquefiable materials have zero shear strength and designing the embankment so that even if some instability occurs, a sufficient portion of the crest of the embankment will remain to prevent a release. Analysis would also need to show that sufficient freeboard is provided to prevent a release from the maximum embankment deformation that may occur.

Evaluations of the potential for liquefaction or the development of excess pore-water pressure can be made based on methods that link material properties, such as the site material's soil classification and standard or cone penetration values, to the documented performance of similar materials during earthquakes. Or, seismic strength can be determined from laboratory testing such as cyclic triaxial or torsional shear testing. In conducting laboratory testing, factors such as the consolidation status of the materials (and the fact that they may not be fully consolidated for many years), the degree of disturbance of "undisturbed" samples, and how well remolded samples are representative of in-situ conditions, need to be considered. Since a material's void ratio is critical to its seismic properties, special care needs to be taken in sampling, transportation, and testing to minimize disturbance and account for void ratio changes.

A one-dimensional analysis, such as the SHAKE program (Schnabel, et. al., 1972; Idriss and Sun, 1992) or a more sophisticated analysis, is used to model the propagation of earthquake induced rock motions through the foundation and the embankment, and determine the induced cyclic stresses. The testing, the seismic strength estimates, and the pore-water pressures modeled in the analyses must properly take into account the state of consolidation of the fines. If, for the expected number of load cycles, the seismic stresses exceed the seismic strength, then liquefaction is indicated and the dam should be redesigned, or should be analyzed to show that even if liquefaction occurred, a release from the impoundment would not occur. Even if liquefaction is not indicated, the potential impact of elevated pore water pressures needs to be evaluated.

Post-earthquake stability should be evaluated to determine whether the embankment has an adequate factor of safety with the earthquake induced elevated pore-water pressures and loss of material strength that may occur. Post-earthquake shear strengths for zones not indicated to liquefy should take into account induced excess pore pressures. If liquefaction is indicated, the strength of liquefied zones can be assigned a value of zero; be based on conservative correlations to applicable back-calculated steady-state strength values from documented cases; or be based on sampling and testing of undisturbed samples which strictly adheres to the protocol of the "steady-state strength" approach. With upstream construction, steady-state testing and analysis must take into account that the fines may be only slightly or partially consolidated and that the effective stress, and thus the steady-state strength, will not likely increase linearly with depth within the fines deposit.

The sampling and testing needed to determine the residual undrained shear strength in the steady-state approach is much more complex than normal shear-strength testing. The residual undrained shear strength is highly sensitive to the void ratio of the material, and without painstaking care to track the void ratio throughout the sampling, transportation, and testing process, and correct the strength for the in-situ void ratio, the results are uncertain. For this reason, this specialized sampling and testing should only be performed by, or under the direction of, persons experienced with this method. The residual undrained strength can also be estimated by a field test, such as the vane shear test, if it can be shown that shearing occurs in an undrained condition. This would likely be the case only for very low permeability deposits.

The post-earthquake deformation analysis should assess the amount of deformation in the embankment, after sliding or slumping of the cross section, where inadequate factors of safety are indicated, or where significant strain-softening or settlement may occur. Excessive settlement or slumping of the embankment due to shaking could result in impoundment failure due to either overtopping or cracking. Deformation estimates are typically based on the amount of movement that would accumulate when the structure's yield acceleration is exceeded. This type of analysis requires that the motions that would occur along the base of the critical sliding mass be determined from a seismic-response evaluation. Since the results of these types of deformation analyses are considered "order of magnitude," ideally the predicted settlement should be a small fraction of the available freeboard. Deformation can also be estimated using more sophisticated analyses, such as finite-element methods.

Where problems with liquefaction or elevated pore-water pressures are indicated by simplified analyses, the embankment should be redesigned, or appropriate, more sophisticated analyses should be performed. Detailed seismic evaluations include:

- Establishing ground motion parameters and earthquake time histories;
- Performing detailed field investigations to determine the dynamic properties and the aerial extent of susceptible foundation and embankment materials.
- Conducting testing and/or analyses to determine the dynamic shear moduli and damping ratios, and their relationships to strain, using geophysical testing, laboratory testing, and/or empirical relationships, as appropriate;
- Determining dynamic shear strength from appropriate empirical correlations with in-situ testing or from laboratory testing (e.g., cyclic triaxial). Empirical correlations should be used with caution and conservatism, and should only be based on carefully conducted and well-documented field testing. Standard penetration test results, for example, must be "corrected" for factors such as overburden pressure, hammer energy, borehole diameter, and rod length.
- Using appropriate analysis procedures to: determine the stresses induced by the earthquake loadings; evaluate the liquefaction resistance of the materials; determine post-earthquake shear strengths and pore-water pressures; assess post-earthquake stability; and perform a post-earthquake deformation analysis.

Whichever methods are used to evaluate seismic stability and deformation, complete details need to be included in the impoundment plan. Design features that would mitigate the adverse effects of shaking and enhance seismic stability, such as providing extra freeboard, using measures to promote internal drainage and consolidation of the fines, widening the embankment so that liquefiable materials are kept away from critical structural zones, and adding a buttress to reduce shear stresses, should be incorporated. Considerably more detail and guidance on seismic stability can be found in FEMA's "Federal Guidelines for Dam Safety: Earthquake Design and Evaluation of Dams" (2004).

17. Upstream Construction - Excess Pore-Water Pressures and Construction Procedures

When a coal company requests approval to raise the height of an embankment by upstream construction over settled fines, suitable tests need to be performed on the fines (subsurface investigation) to demonstrate that the fines have sufficient strength for stability and support of the added material. A special concern that must be addressed is the development of excess pore-water pressures during the construction of embankment stages founded on the settled fines. When an embankment is raised by pushing material out onto settled fines, the weight of the push-out material is initially transferred to the water in the pore spaces of the fines. Until drainage can occur to relieve this condition, the excess pore-water pressure that is generated reduces the effective shear strength of the fines and can cause a bearing capacity or slope stability failure. At impoundments where the coal processing procedures result in less sand-size particles in the slurry, potential problems with upstream push-outs are increased because the slurry delta contains more silt and clay-sized particles, that is, materials with lower permeability and lower strength.

Several upstream slope failures have occurred at slurry impoundments because of the development of excess pore-water pressures. To avoid such failures, the rate of placement of push-out material needs to be limited. Where the development of excess pore pressure is a concern, plans should include limits on the rate of fill placement, and the installation of quick-response piezometers may be required. The piezometers allow the pore-water pressures to be monitored to ensure that they stay within pre-defined acceptable limits, which are determined from stability analyses.

Besides the stability of the impoundment, plans should address upstream push-out issues related to the safety of the equipment operators working on the push-out. Incidents have occurred during push-outs where a portion of the pad has sunk into the fines and equipment working on the pad has ended up completely submerged. Plans should address the safety precautions to be taken in constructing push-outs. These should include:

- Establishing an exposed delta of fine refuse before starting the push-out;
- Maintaining the water level in the impoundment at the lowest practical level during push-out construction;
- Establishing the initial push-out by working one continuous pad of material from firm, established areas;
- Restricting the thickness of the initial push-out to 5 to 8 feet;
- Limiting or phasing the length of push-outs so that construction equipment stays reasonably close to firm, established areas;
- Prohibiting dumping by trucks near the edge area of push-outs;
- Restricting push-out construction to daylight hours or times when the area is sufficiently illuminated to provide good visibility;
- Using low-ground-pressure equipment where there is concern for the bearing capacity of the push-out;
- Providing radio communications for push-out construction equipment;
- Examining the work area frequently for signs of instability such as cracking or sinking, and suspending work in areas exhibiting such indications; and
- Having an engineer with knowledge of slope-stability issues evaluate push-out development to determine whether the procedures are creating a potentially hazardous situation for the equipment operators.

Because the issue of excess pore water pressures may not be fully understood by equipment operators, for any plan that includes upstream construction, it is recommended that the design engineer meet with the construction personnel to ensure that they understand the significance of excess pore-water pressures and the potential hazards in push-out construction. As has happened in some of the failures that have occurred, some equipment operators may mistakenly think that when it comes to upstream push-outs, “the thicker, the better,” while not realizing the detrimental effect of placing too much fill, too soon.

18. Foundation Exploration

A program of subsurface exploration should be conducted to determine the geologic stratigraphy; the orientation, frequency, and condition of geologic discontinuities; and the pertinent

engineering properties of the foundation materials. At a minimum, borings are normally taken across the axis of the embankment; up and down the valley; and at the location of spillway and decant structures. The specific number and location of borings cannot be determined before the investigation begins, because the spacing depends upon the uniformity of the conditions that are found. It is important to remember that a drill hole represents an extremely small percentage of the foundation area or the volume of an embankment. A sufficient number of samples must be taken and tested to produce confidence in the interpolation between boreholes.

If underground mines may be present near an impoundment, additional borings should be taken as necessary to verify or determine the location and extent of the workings and to evaluate the adequacy of the overburden barriers separating the mine workings and the impoundment site. Both the foundation and reservoir areas need to be investigated. Borings should extend into the floor of the coal seam(s) and should provide sufficient information to allow for an assessment of subsidence and breakthrough potential. These topics are discussed further in item No. 25 of these guidelines.

The site evaluation program should be determined by a qualified engineer or engineering geologist, with experience in subsurface investigations. Complete results of the exploration program need to be provided in the impoundment plan.

19. Foundation Preparation

Before construction of an embankment is started, appropriate measures must be taken to prepare the foundation. The specifications section of the plan should provide complete details on foundation preparation including:

- Removal of all vegetation and topsoil;
- Removal or treatment of unsuitable materials which could provide a plane of weakness or a path for excessive seepage;
- Cleaning of all loose or unsuitable material from surfaces and contacts where structural fill is to be placed;
- The depth and width of seepage cutoffs;
- Compaction of existing unconsolidated foundation materials;
- Treatment of open joints, such as hillseams, which have the potential to provide a seepage path through an abutment;
- Provisions for cleaning out and sealing, or otherwise treating, exposed joints, cracks, or openings that could provide a path for internal erosion or excessive seepage;
- Removal of loose foundation rock, overhangs, and abrupt changes in slope, and flattening of abutment slopes that are too steep to allow adequate bonding with compacted fill layers;
- Where plans include the excavation of overburden within the reservoir area, measures to prevent seepage problems through exposed foundation layers;
- Installation of drains and filters to intercept springs and foundation seepage; and
- Backfilling and/or drainage of mine openings.

Plans should also require that an engineer who is familiar with the design plan, preferably a representative of the designer, examine and accept the foundation preparation before fill is

placed. Where unanticipated conditions are found during foundation preparation, plan approval needs to be obtained for the design of new or changed foundation treatments and construction procedures.

20. Embankment Fill Placement and Compaction Specifications

Proper compaction of embankment material is one of the most important elements in the construction of a safe impoundment. Structural fill is compacted to increase density and shear strength and to decrease compressibility and permeability. To help ensure that embankments are compacted uniformly and adequately, items addressed in the construction specifications should include the following:

- Limits need to be placed on the minimum dry density, range of placement water contents, maximum lift thickness and maximum particle size;
- Structural fill should be placed in continuous, horizontal or nearly horizontal, compacted layers;
- The top surface of a compacted layer that is too dry or too smooth to bond properly to the next layer needs to be adequately moistened and/or scarified;
- Special attention should be paid to achieving adequate compaction and bonding at fill/abutment contacts, and at closure sections;
- When compacted fill is placed over an existing embankment slope or a soil abutment slope, any weathered or freeze/thaw affected surface material needs to be removed or reworked and the new fill needs to be keyed into the existing slope with horizontal steps;
- Before the crest of an existing embankment is raised, weathered or freeze/thaw affected material on the existing crest should be removed – this is especially important in coarse coal refuse embankments where weathered, degraded crest material can create horizontal, relatively impervious layer through the embankment;
- Embankment materials are not to be compacted when either the materials themselves, or the surfaces they are to be placed on, are frozen;
- The surfaces of benches or crests should be graded to drain in the upstream direction to prevent runoff from eroding the downstream slope; and
- Whenever embankment material contains particles too large for proper inclusion in the laboratory testing conducted to establish the maximum dry density, an appropriate correction needs to be applied to the unit weight and water content. This correction is to account for the oversized material and to ensure that the measured field density, when expressed as a percentage of the laboratory standard, does not overestimate the true degree of compaction. Correction methods are addressed in the standards of the American Society for Testing and Materials (ASTM D4718) and the American Association of State Highway and Transportation Officials (AASHTO T224).
- If the roller-pass method is proposed for determining required fill density, the following points should be addressed:
    1. The variability of the material's moisture content must be taken into account when the compacted density is sensitive to moisture;
    2. The density and moisture content need to be related to the material-property testing, such as shear strength testing;

3. Field density and moisture testing still needs to be conducted to verify and provide documentation of adequate compaction and acceptable moisture content;
4. The roller pass test should be performed for each different piece of compaction equipment and the values should be checked periodically, and anytime a significant change occurs in the fill material.

- When a coal company proposes to construct a dam using conveyors and dozers to place the fill, long pushes can make it difficult to achieve systematic compaction. In addition, construction quality control is difficult to monitor with these construction methods. This can lead to non-uniform compaction and problems with seepage and strength. Under these circumstances, a detailed material-handling study needs to be performed to demonstrate that the equipment allocated to the dam construction is sufficient to properly place and compact the structural fill in accordance with the specifications. Since most conveyors provide little storage capacity for excess material, the plan should include procedures to be taken in the event of incidents, such as equipment breakdowns, which interfere with proper material placement.

In arriving at compaction specifications, it is prudent that the recommendations and practices of authoritative and experienced dam builders be used for guidance. The following recommendations are made for the structural fill portions of impounding structures:

- Material should be compacted to at least 95 percent of the maximum dry density as defined by the standard Proctor test, with the placement water content not exceeding the range of -2 to +3 percent of optimum. When conditions warrant, corrections should be applied to account for oversized particles.

- For coarse coal refuse, the lift thickness should not exceed 12 inches. When fine-grained soils are used for embankment construction, lift thickness should not exceed 8 inches. (Plans may allow for the use of thicker lifts during initial push-outs for upstream stages. However, once a stable working surface is established, placement should proceed at the lower lift thickness.)

Plans need to require that material not meeting the compaction specifications will be re-worked, or removed and re-compacted, if necessary, until adequate results are obtained. For materials too coarsely graded for application of Proctor-type tests, compaction specifications should be based on relative-density testing.

Less stringent compaction specifications than those cited above would not generally be consistent with current, prudent engineering practice. Plans with such specifications are not recommended for approval unless a detailed technical justification, which demonstrates that the proposed practice would have no adverse effect on the safety of the impoundment, can be provided by the designer. The designer would need to show through testing and analyses that all potential problems, including settlement, cracking, piping, instability, stratification, and seepage, have been taken into account in the design and that compensating design features have been incorporated. It should be noted that less stringent compaction specifications can generally be used in areas that can be shown to be "non-structural" portions of the embankment, that is,

portions not necessary for the stability of the embankment. If included in an impoundment design, such areas should be clearly delineated on plan drawings.

Following is some pertinent information related to compaction specifications:

- "Recommendations - Based on the findings of this study, it is recommended that coarse coal refuse, typical of eastern United States coal regions, be compacted near the optimum moisture content to a density greater than 95 percent of maximum dry density determined in accordance with ASTM D-698. Compacted lifts should not be greater than 1 foot in thickness." Source: S. K. Saxena, et. al., Compaction Criteria for Eastern Coal Waste Embankments, Journal of Geotechnical Engineering, February 1984.

- For earth dams greater than 50-feet high, the required density is 95 percent of Modified Proctor, at moisture limits of -1 to +2 percent of optimum, with a maximum permissible compacted lift thickness of 12-inches. Source: Naval Facilities Engineering Command, Foundations and Earth Structures, 1986, Table 4.

- "Selection of design densities, while a matter of judgment, should be based on the results of test fills or past experience with similar soils and field compaction equipment. The usual assumption is that field densities will neither exceed the maximum densities obtained from the standard compaction test nor be less than 95 percent of maximum densities derived from this test." Source: U. S. Army Corps of Engineers, Earth and Rockfill Dams, July, 2004

- Cohesive soils controlled by Proctor test having 0-25 percent plus No. 4 fraction by weight should have a minimum acceptable density of 95 percent and a desirable average density of 98 percent; and cohesive soils having 26-50 percent plus No. 4 fraction by weight should have a minimum acceptable density of 92.5 percent and a desirable average density of 95 percent. Cohesive soil with more than 50 percent plus No. 4 fraction by weight should have a minimum acceptable density of 90 percent and a desirable average density of 93 percent. These criteria are provided in the Bureau of Reclamation's Design of Small Dams, which presents procedures for the design of dams with heights "not exceeding 50 feet." These compaction percentages, which are based on experience with 44 dams in the western U.S., apply to the minus No. 4 fraction and for moisture-content limits of -2 to +2 of optimum moisture. Permeability tests are recommended on cohesive soils that contain more than 50 percent gravel if used as a water barrier. Source: Bureau of Reclamation, Design of Small Dams, 1987, Table E-1.

21. Frequency of Testing to Verify Compliance with Compaction Specifications

Tests need to be performed during the construction of an embankment to determine compliance with the approved plan's moisture-density specifications and to help detect any significant changes in the material properties over the construction period. Plans should require that such tests be conducted at the following minimum frequencies:

- One field density test for every 2,000 cubic yards of compacted structural fill, with at least one test per lift;
- One field density test for every 200 cubic yards of compacted backfill in trenches or around structures, with at least one test per lift. (Note: With small diameter pipes, where the total volume of backfill may be small, more frequent tests than indicated by this criterion should be performed);
- One field density test anytime there is difficulty achieving compaction or suspicion of the effectiveness of compaction; and
- Supplementary laboratory compaction curves for at least every 20 field density tests.

In cases where it can be shown that the source material is consistent and a record of consistent test results is established, less frequent testing may be considered, based on the use of a specific compaction procedure, if justification is provided.

Compaction testing requirements should also include:

- Performing field tests at random locations in the fill, but also checking areas that appear softer or which are suspected of having received less compactive effort;
- Re-working, or removing and re-compacting, if necessary, material that does not meet the compaction specifications, until acceptable results are achieved;
- Testing in a manner that provides density and moisture values that are representative of the entire compacted lift thickness; and
- Keeping records of compaction test results, as well as test locations and elevations, at the mine.

Any time there is reason to suspect that the characteristics of the construction material have changed, such as due to a change in preparation plant process, a change in the coal being processed, or unusual compaction test results, the material should be further investigated. Grain-size, compaction, shear-strength, and other tests should then be performed as warranted.

22. Seepage and Phreatic Surface Level

All earthen dams are subject to seepage through the embankment, foundation and abutments. If uncontrolled, seepage can cause slopes to become unstable by creating internal water pressures and reducing the effective strength of embankment materials. Uncontrolled seepage can also cause internal erosion or piping if hydraulic gradients are large enough to move soil particles. Over 30 percent of all dam failures occur due to seepage or piping problems. These problems are normally prevented by designing and incorporating a relatively impervious zone in the upstream portion of the embankment and/or internal drainage features in the downstream portion.

All impoundment plans must demonstrate adequate factors of safety against slope instability before approval is granted. An integral part of any slope stability analysis is the embankment's maximum anticipated saturation or piezometric level. The piezometric level used in the stability analysis needs to be substantiated with appropriate seepage analyses. Where applicable, it is also

good practice for monitoring purposes to determine the highest phreatic surface that correlates to the minimally acceptable slope stability factor of safety (usually 1.5).

The long-term stability analysis for each stage should be based on a phreatic surface which is at the maximum anticipated level for the long-term steady-state seepage condition. In cases where impoundments are designed to store a significant amount of water above the normal pool level during the design storm, the stability analyses should be conducted with a correspondingly high phreatic surface, unless it can be shown that the water would be evacuated before the higher saturation level could develop. Seepage analyses should recognize that settled fines deposited to form a delta along the upstream slope will not provide an effective seepage barrier if the pool level rises above the delta, placing water against the upstream slope. Where the permeability of the embankment is such that storm water would be evacuated before a higher phreatic level could develop, then the phreatic level should be based on the maximum normal pool level as controlled by either a decant or open-channel spillway.

Different methods such as flow-net construction and numerical techniques are available for estimating an embankment's maximum anticipated phreatic surface for steady-state conditions. The Corps of Engineers' Seepage Analysis and Control for Dams, EM-1110-2-1901, provides a summary of seepage analysis and control for dams.

The coefficients of permeability used in a seepage analysis should be either conservatively chosen or determined from laboratory or field permeability tests. Since permeability values are generally regarded as being accurate to only one order of magnitude, this accuracy should be kept in mind for all seepage analyses.

It is well documented that embankments compacted in layers normally demonstrate a higher permeability in the horizontal direction than in the vertical direction. The "permeability ratio" is commonly used to express the ratio of the horizontal to vertical permeability. The available literature shows a wide range of permeability ratios, from less than 1 to over 100, for earthen embankments. Based on the guidelines of dam-safety agencies such as the Corps of Engineers and the Bureau of Reclamation, and other published permeability ratios, embankments should be designed for a permeability ratio of at least nine, but designers should determine whether a different ratio is appropriate for a particular site.

Internal drains are commonly incorporated in embankments to lower the phreatic surface, control internal seepage, and help stabilize the embankment. To prevent piping of embankment material into the drains, filter criteria needs to be met between adjacent materials of different gradations. See the following sections on "Graded Filters" and "Use of Geotextiles" for additional information. In addition, the drain material must have sufficient permeability and the drain must be located and sized to provide adequate drainage capacity. Due to uncertainties with the design and performance of drains, they are normally designed with a flow capacity equal to at least 10 times the expected seepage flow rate. A drain capacity factor of safety above 10 may even be warranted for conditions involving semi-turbulent and turbulent flow conditions. For turbulent flow conditions, where Darcy's law is invalid, publications by the Corps of Engineers (1993) and Leps (1973) provide information for determining flow rates. Flow through a gravel or coarser material is likely to be turbulent.

Drain material should be placed to prevent segregation. To be able to construct zones of drainage and granular filter material without contamination, minimum dimensions of at least 5 feet are preferred. A 3-foot thick zone is the minimum that should be considered and would require close construction supervision to ensure proper installation.

Plans need to include a detailed technical justification demonstrating that the location, dimensions, and materials for proposed drains are consistent with the phreatic surface level used in the design. For a finger-type drain, for example, plans should show that the width, thickness, and location of the drain are sufficient to ensure that the phreatic surface will be directed into the drain instead of extending past it. Plans should require that drain installations be accepted by an engineer who is familiar with the design requirements before the drains are covered.

Any proposed use of geo-composite drainage material should include information showing that the selected material can handle the seepage rate with a conservative factor of safety, will prevent piping, and will not become clogged. The potential impact of compressive forces on the in-plane flow capacity should be substantiated.

A sufficient number of piezometers should be installed in embankments to monitor the phreatic surface so that seepage analyses can be verified and potential seepage problems can be identified. Plans should include graphs or tables that readily show the allowable water elevation or reading in each piezometer for each stage, based on maintaining an acceptable factor of safety for slope stability. If the trend of piezometer readings indicates that the phreatic surface may rise above the allowable level for any given stage, or if a reading exceeds the allowable level, the situation should be evaluated by the design engineer, measures should be taken to reduce the phreatic surface, and the stability of the embankment should be reassessed.

23. Graded Filters

A filter provides a transition where seepage may occur across the boundary between finer and coarser materials within an embankment. A filter's purpose is to prevent the migration of the finer material into the voids of the coarser material, while allowing seepage to pass through freely. Filters are important because the progressive migration of particles with the flowing water, or piping, can result in the formation of a cavity through the dam and lead to failure. And if seepage can not pass freely through a filter, unanticipated pore-water pressures can develop and lead to slope instability.

Filters typically need to be provided where seepage will enter an internal drain. By preventing particle migration, the filter also helps to keep the drain from becoming clogged. Filters also need to be provided where seepage can occur between different zones of material, such as between coarse refuse and spoil. The filter zone itself must also be designed so that it will not erode into the coarser zone or the drain material. Two types of filters are granular materials and geotextiles. The use of geotextiles is addressed in the following section of these guidelines.

To function properly, granular filter material must exhibit a specific grain-size distribution or grading. MSHA recommends that filter design requirements be met by following the filter

design procedure developed by the Soil Conservation Service (now the Natural Resource Conservation Service, NRCS). This procedure is found in the NRCS's Gradation Design of Sand and Gravel Filters (1994). The Bureau of Reclamation has also adopted this method (Design Standards - Embankment Dams, No. 13, Chapter 5, Protective Filters, June, 1999). If any other method is used for filter design, sufficient documentation and proof of acceptance should be submitted.

Many of the gradations examined by MSHA relative to filter design exhibit broad gradation bands for the protected material. To ensure that filter criteria is met for all embankment materials, worst case, rather than average gradations, should be evaluated. Filters should be designed using the protected soil that requires the smallest D_{15} size for filtering purposes. D_{15} refers to the particle size on the gradation curve at which 15 percent, by dry weight, of the material is finer. For drainage purposes, the design should be based on the protected soil that has the largest D_{15} size.

When using perforated drainpipe, criteria to prevent migration of the adjacent granular drain material into the pipe should be applied. To prevent fine sand particles from blocking off pipe openings, many designers recommend that collection pipes be embedded in a gravel envelope, which is in turn surrounded by a sand filter. A criterion commonly used for uniformly graded material adjacent to a perforated pipe is that the D_{85} of the material be two or more times larger than the maximum perforation size.

Filter and drain materials need to be free of deleterious material and capable of resisting mechanical breakdown, chemical attack, weathering and deterioration by time or water. Also, filter gradations should be designed to minimize the potential for segregation during storage or construction.

Limestone and calcite-cemented sandstones can degrade relatively quickly where acidic leachates exist and should not be used in the construction of filters and drains. Refer to section 8.6 of the Engineering and Design Manual - Coal Refuse Disposal Facilities for additional material-handling and filter construction guidelines.

ASTM C-33 fine concrete aggregate generally meets gradation requirements for a filter. However, the NRCS found that for dispersive clay and clays having a D_{85} less than about 0.05 mm, a finer sand is required having a D_{15} of about 0.10 to 0.20 mm. It has been suggested that specification of ASTM D1073, Bituminous Mixture, Gradation No. 3 will meet filter requirements for these very fine clays.

The ability to construct filter and drainage zones without contamination or segregation of the materials, while ensuring that the specified minimum widths are met, is an important consideration. Filters, drainage blankets, etc., that are so thin that a small amount of contamination during construction would reduce the flow capacity below design requirements are not considered adequate.

Submitted plans need to show that proposed filter materials meet the requirements for piping prevention, permeability, durability and constructability. Prudent practice requires that, prior to

being buried, filter installations be observed and accepted by an engineer who is knowledgeable about filters and specific plan requirements, preferably a representative of the designer.

24. Use of Geotextiles as a Filter

Impoundment plans in which a geotextile is proposed as a filter must include the basis for specifying the particular geotextile or geotextile characteristics. This should include showing that accepted design criteria with respect to soil retention, permeability, clogging, and constructability have all been considered and met. To perform acceptably as a filter in a drainage application, a geotextile must function as follows:

- Retain the protected soil to prevent piping;
- Have sufficient permeability to prevent the build-up of water pressure;
- Not become clogged; and
- Have sufficient strength to survive the construction process.

For information on the selection criteria and installation procedures for geotextiles, consult references such as "Geosynthetic Design and Construction Guidelines" (1998) and "Geotextile Engineering Manual" (1985).
Prudent practice requires that critical geotextile installations be observed and accepted by an engineer who is knowledgeable about geotextiles and filter requirements and familiar with the placement procedures specified in the plan, preferably a representative of the designer. For high and significant-hazard potential dams where problems with the geotextile filter could lead to failure of the dam, in addition to meeting accepted retention and permeability criteria, the following are necessary:

- Evaluation of clogging potential needs to include an appropriate soil-fabric filtration test, such as a gradient ratio test (ASTM D 5101) or a hydraulic conductivity ratio test (ASTM 5567); and
- Sufficient instrumentation needs to be included in the plan to allow both the piezometric levels and seepage quantities - that would provide an indication of performance problems with the geotextile - to be monitored.

Designers and plan reviewers are cautioned that testing performed by the U. S. Bureau of Mines, although inconclusive, indicated a potential for plugging of geotextile fabric when used as a filter in a coal waste embankment. Concerns for the formation of a precipitate, or the growth of bacteria on the cloth, have been raised. Because of the potential for clogging, if geotextiles are proposed, products with the largest opening sizes that provide the maximum flow capacity while maintaining the soil retention requirements should be specified.

Problems can occur with geotextile installations due to incorrect or poor construction procedures. This is why all critical installations should be observed by a representative of the designer who is knowledgeable about the important function that the geotextile serves. In general, the manufacturer's recommendations for installation should be followed. Particular attention should be given to the following items.

- Geotextiles should be secured by sewing, pins, staples, or weights, as necessary to prevent disturbance by construction operations or wind.
- Where seams are to be formed by overlapping, the overlay should be at least 2 to 3 feet, but the specific conditions should be evaluated to ensure that overlaps are sufficient to prevent the fabric seam from opening up under load.
- For internal drains, geotextiles should be overlaid so that as seepage moves downstream and enters the drain, it will not tend to flow between the geotextile sheets, i.e., along the top of a blanket drain, upstream geotextile layers should overlap downstream layers, with the order being reversed along the bottom of a blanket drain.
- When used under riprap or other spillway lining, upstream geotextile sheets should always overlay downstream sheets.
- In preparing surfaces for fabric placement, depressions, holes, and voids should be filled so that the fabric will not have to bridge them and possibly be torn when cover material is placed. Fabric should not be placed over sharp or angular rocks that could tear or puncture it. An intermediate layer of compatible finer material should be placed over such rocks as a bedding layer to protect the geotextile.
- Geotextiles should be placed so that voids between the geotextile and the protected soil are minimized to prevent fines from accumulating behind the fabric and clogging it.
- A filter surface area as large as possible should be provided (e.g. it is better to place geotextile around the periphery of a drain trench with gravel and a collection pipe inside, than to place the geotextile directly around the pipe, where the surface area is smaller).
- In placing material or using equipment on a geotextile, care must be taken to avoid punctures or tears. Fabrics must be specified that have adequate tensile, puncture and burst strength for the conditions and construction procedures that will be involved. Where applicable, specifications should limit the size and drop height of rocks to be placed on the fabric. Generally, stones greater than 250 pounds should be placed with no free-fall. Field trials should be made to ensure that no damage will occur due to the construction procedures. A cushion layer of finer material, compatible with the fabric's function, may be required to protect the fabric.
- Geotextile material should be covered as soon as possible to prevent degradation from sunlight. Manufacturer's recommendations should be followed regarding exposure times.

25. Mine Workings Under or Near Dams and Impoundments

If there is mining under or near an impoundment site, plans need to include a detailed evaluation of the potential for any ground deformations or strains caused by the mining to affect the safety of the dam. Also, plans need to show that there are adequate factors of safety to prevent the contents of the impoundment from breaking into any underground mine workings. In these evaluations, both present and future mining should be considered. Information related to these issues is provided in the following.

Accuracy of Mine Maps: In investigating the potential for mining to affect a dam, or the potential for a breakthrough into mine workings, designers must consider that the accuracy and completeness of mine maps can vary widely. Experience has shown that some mining may not be shown on a mine map, or a map may be missing, or workings may be depicted hundreds of

feet from their actual location. Near outcrops, limited access due to either poor roof conditions or the practice of not supporting final cuts may be additional reasons that workings are not accurately surveyed.

It is recommended that the same survey coordinate system be used for both the impoundment survey and underground mine mapping. Use of a common coordinate system for the impoundment and mine workings should improve mapping accuracy and planning relative to mining under or near the impoundment. Preferably, both surveys are based on the state plane coordinate system.

Designers should exhaust all possible sources of information on mining and mine maps in the area, with emphasis on locating certified, final mine maps. Additionally, the entire foundation and basin area should be walked and examined by an engineer or geologist knowledgeable and experienced in mining and geotechnical matters.
The potential presence of mine workings significantly increases the scope of an impoundment's subsurface exploration program. Since mine maps can be inaccurate or incomplete, impoundment plans need to show that the extent of mining has been verified in critical locations near the reservoir and the embankment. This should be done by drilling, possibly in conjunction with geophysical methods. In general, sufficient exploration should be performed to check the accuracy of the mining information, and identify all geologic, soil, and water conditions needed to evaluate the potential for subsidence to affect the dam and the adequacy of the overburden to act as a barrier in preventing a breakthrough into the mine workings.

The accuracy of mine mapping should be checked by first identifying the locations where the conditions appear to be most critical. This should be based not only on the locations where the total amount of cover, or the outcrop barrier width, is at a minimum, but needs to account for other locations where the competent rock portion of the overburden may be reduced due to a deeper soil layer, or other reasons. For example, there may be significant differences between the thicknesses of the soil layer lower in a valley versus higher on the hillside. Several of these more critical locations should be investigated. How many will depend on how far the mining is expected to be from the impoundment, the level of uncertainty, the results that are found, and the degree of conservatism to be used by the designer on any remedial measures.

In an outcrop barrier situation, main concerns are to verify how close to the surface the mining has occurred, assess the engineering characteristics of the overburden and barrier material, determine whether the inby pillars have been first-mined only, ascertain whether lower seams have been mined in the area, and establish whether auger or highwall mining has reduced the size of the barrier. Several of the more critical areas should be investigated to verify the extent of mining and determine the overburden conditions. If the mapping is found to be inaccurate in any of those areas, then additional areas will need to be checked.

Where mining has occurred below the level of the bottom of the reservoir, the main concerns are to determine the depth to mining, the extent of mining, the characteristics of the overburden, coal, and mine floor, and the size and condition of the pillars. Where multiple seam mining has occurred, this information applies for all mined seams. Whether or not the pillars have been second-mined is a critical piece of information to evaluating the subsidence and sinkhole

potential. Where possible, borings that are drilled for other purposes, such as foundation investigation, should be extended through the coal seam(s) level to provide additional points to confirm whether or not mining has occurred, and to provide pertinent information to allow evaluation of pillars, roof and floor stability.

Establishment of "Safety Zone": The most prudent and recommended design approach is to locate the embankment and reservoir far enough from mining that they will not be affected by subsidence and not create the potential for a breakthrough. To do this, the area of mining influence, as defined by a draw angle, should be outlined and barriers of sufficient size to preclude the impoundment from being affected should be delineated. This establishes a "safety zone" beneath and around the impoundment where no mining is permitted. The extent of the "safety zone" should be conservatively estimated, based on the specific site conditions and local experience, and considering that tensile strains as low as 0.1% - 0.3% are sufficient to cause cracks in some earthen materials.

All information used in determining how close to an impoundment mining can safely be conducted, or the location of the "safety zone," should be fully documented in the impoundment plan. Substantiation should include detailed geologic sections and mine maps. The analysis of the subsidence potential needs to include the technical basis for the proposed extent of the safety zone. "Results of Research to Develop Guidelines for Mining near Surface and Underground Bodies of Water," (IC 8741) and "Criteria for Determining When a Body of Surface Water Constitutes a Hazard to Mining," can be consulted for information concerning safety zones.

New Mining near Existing Impoundments: A "no mining zone" should be established around existing impoundments, or when a new impoundment is designed, to prevent problems from future mining. Due to the uncertainty of long-term support, the development of entries near or under dams should be avoided. Only under favorable conditions and where entry development is essential for haulage or ventilation safety should limited mining be considered under an existing dam. Since full-extraction mining methods, e.g., longwall mining or pillar extraction, affect the surface in virtually all cases, such mining is normally not acceptable either under a dam, or within a zone of influence of the dam. The extent of mining that may be safely conducted under the reservoir portion of an impoundment depends on the overburden and mining conditions. In addition to the standards related to impoundments, standards pertaining to mining under bodies of water, contained in 30 CFR 75.1716 through 75.1717, need to be met.

Effects of Mining on a Dam: One of the requirements for a safe dam is that deformations be minimized so that cracking of the dam is prevented and adequate freeboard is maintained. Another requirement is that seepage through a dam and its foundation be minimized and controlled. Mine subsidence and mining-induced strains can jeopardize these dam safety requirements.

When mine subsidence occurs, tensile strains are induced and zones of tension are created at the ground surface. As a result, cracks can occur in soils and mine-waste materials because such materials have low resistance to tensile stress. Openings can occur in the foundation or abutment rock due to cracking or the concentration of tensile strains along an existing joint. Subsidence can cause conduits to be pulled apart, compressed, or be subject to differential settlement.

A crack in a dam, an open rock joint in its foundation, or a damaged conduit can result in internal erosion due to the concentration of seepage. Internal erosion involves the progressive removal of soil particles, carried away by the seeping water, with the formation of an opening back through the embankment or foundation. The amount of seepage progressively increases as more and more material is carried away with the flow. This process can lead to the eventual failure of the dam. Over 30 percent of all dam failures occur due to seepage or piping problems.

Differential movements resulting from subsidence can cause other problems by affecting the function of internal design features such as filters and drains. These problems can result in higher pore-water pressures than the dam was designed for and can cause slope failure. Subsidence also can reduce the amount of freeboard, and could result in the dam being overtopped during a storm.
For these reasons, a site that has been undermined or under which mining is planned may not be suitable for the construction of a dam. Designers should investigate alternative sites. Where use of an undermined site must be proposed, designers should realize that a more comprehensive foundation investigation is called for, that extensive remedial measures may be required to make the site acceptable, and that additional safety features are normally required in the dam's design. In such cases, plans must include detailed technical evaluations of the potential for the dam to be affected. In the case of total or high percentage extraction, plans must include evaluations of how the potential mining-induced strains and ground movements would affect the foundation and embankment. Full extraction mining methods will affect the surface in virtually all cases, with the surface strains generally being larger the shallower the mining depth. For partial extraction, issues such as sinkhole development, pillar crushing, and pillar punching need to be addressed. Analyses of potential mining-induced movements and strains should address shearing, bed separation, and tilting, in addition to the effects of tension and compression zones. Plans need to include evaluations of all applicable potential failure modes, along with the complete technical basis for the evaluations.

Pillar/Floor/Roof Strength Evaluations Related to Dams: The stability of the pillar, roof, and floor must be evaluated in cases where a dam or reservoir is proposed over existing room-and-pillar mining and in cases where a limited number of entries might be proposed under a dam. Engineering properties used in the evaluations should be fully substantiated.

Loss of support due to coal pillar failure allows the mine roof to sag or collapse. Furthermore, failure of one pillar transfers the load to other pillars, and may lead to progressive pillar failure over a larger area. Pillars whose failure could affect impoundment sites should have conservative margins of safety against crushing, with factors of safety of at least 2.0 for the long-term support of critical areas. Higher margins of safety should be used in multiple seam mining cases to account for the additional uncertainty of factors such as load transfer and stress concentrations. Since different methods of evaluating pillar strength can indicate a significant variation in safety factors, consideration of several methods is suggested and the use of a conservative method is warranted. Where existing pillars are found to be inadequate, compensating measures, such as additional support from grouting or backfilling, need to be provided.

Where the cover is shallow, the potential for sinkhole development should be evaluated. A sinkhole is a local depression or opening in the ground surface caused by the collapse of the mine roof strata. Any area where the cover over a mine entry includes less than 100 feet of "solid" strata is a concern for sinkhole development. However, there are documented cases of sinkholes developing where the overburden thickness approached or exceeded 200 feet.

Preliminary information for evaluating the likelihood of sinkhole development is provided in Bureau of Mines Information Circular 8741, "Results of Research to Develop Guidelines for Mining Near Surface and Underground Bodies of Water," (1977). In general, the ability of the roof strata to span the opening, with an adequate factor of safety, needs to be determined considering the effect of rock discontinuities and weathering. Where sinkhole potential exists in the vicinity of an impoundment, positive measures, such as mine backfilling, should be taken to prevent them from developing, or the impoundment should be located a safe distance away.

The potential for subsidence due to pillars punching into the floor also needs to be analyzed. Pillar punching occurs when the load on the pillar exceeds the bearing capacity of the strata beneath the pillar. This may be caused by loss of strength due to saturation of the floor material, additional loading from the weight of the embankment and impounded slurry/water, transfer of load due to the failure of other pillars, or loss of buoyant pressures from a lowered mine pool. Experience in the mine and the potential for softening of the floor due to moisture should be evaluated

Mine Openings, Auger Holes, or Highwall Mining in Abutment Areas: Seepage into mine openings, if not adequately controlled, can cause embankment material to be carried with the flow, weakening the embankment and possibly leading to an embankment failure or a breakthrough into the mine. Designers should consider that with downward or horizontal flow into a mine opening, the forces of gravity are working with the seepage forces to promote internal erosion (versus the critical gradient typically associated with upward flow near the toe of a dam), and that it only takes one area of erodible material to cause a problem.

The importance of locating mine openings, auger holes or highwall mining entries, during the site investigation phase, cannot be overemphasized. The openings may be hidden if the mined area was backfilled, reclaimed, or occurred long ago.

Where mine openings or auger holes are present in abutment areas, plans need to include analyses showing that potential problems due to deformation and seepage have been accounted for in the design. In such cases, plans normally include provisions to provide support by backfilling the openings, and to control seepage by installing filters, drains, and/or low-permeability barriers outside the backfilled openings. In accordance with prudent practice, plans should require that the backfilling and treatment of mine openings be accepted by an engineer who is familiar with the design requirements before the area is covered.

Embankment Design Features to Compensate for Mining Effects: If there are no alternatives, and an impoundment is proposed on a site that is already undermined, specific features are expected to be incorporated into the design to allow the embankment to safely withstand the

potential effects of the mining. Design measures that should be considered in such cases include but are not limited to the following:

- conducting a more extensive foundation investigation to verify the accuracy of the mine maps, locate unmapped workings, verify the extent of any auger or highwall mining, and locate and characterize fractures, open joints, and zones of high permeability;
- backfilling or grouting the mine openings in critical support areas to minimize the amount of movement which can occur;
- using downstream construction to avoid the potential for subsidence or a breakthrough to cause loss of support for upstream stages, and to create an impounding structure more resistant to the potential effects of subsidence;
- taking special precautions during foundation preparation to ensure that any open joints or cracks in the rock are adequately treated, such as by grouting;
- specifying a wide dam cross-section and crest width to provide increased mass and greater resistance to piping failure;
- maintaining an ample amount of freeboard to compensate for the maximum potential subsidence;
- specifying larger drain and filter cross-sections, so that these internal features would continue to be functional with the maximum subsidence;
- locating any decant conduits over unmined areas;
- compacting materials at water contents slightly wet of optimum to increase their ability to deform without cracking;
- incorporating design features, such as a grout curtain and an upstream impermeable zone in the embankment, to minimize the amount of seepage through the dam and its foundation;
- incorporating internal drainage features, such as a chimney drain, to collect seepage and discharge it in a controlled manner;
- using wide zones of materials with "self-healing" characteristics, to act as crack stoppers;
- installing ground settlement monitors at several locations in the strata between the mine and the dam to provide an early indication of subsidence; and
- specifying a comprehensive monitoring program for the dam (seepage rates, movement, piezometric levels, etc.)to provide for the early indication of a potential problem.

Proposed safety measures must be fully documented in the plan that is submitted to MSHA. Plans should include detailed geologic information, mine maps showing present mine layout and future mining projections, an evaluation of pillar and floor stability, analyses of subsidence and sinkhole potential, and an evaluation of the cracking and piping potential of the embankment and foundation materials. The subsidence analysis should describe existing and anticipated movements and strains, how they were evaluated, and what specific design measures were incorporated to compensate for present and potential subsidence effects.

In general, a designer should include redundancy in the design so that the disruption or failure of any one feature would not jeopardize the safety of the dam. Required features must be selected and evaluated on a case-by-case basis depending on specific site conditions, especially the hazard potential. Plans that involve undermining and that are submitted without conservative

defensive measures, or without adequate justification based on an appropriate level of testing and technical analyses, should not be approved.

Monitoring of mining-induced effects on a dam: In any case where mining induced deformations could have an adverse effect on the dam, dam performance should be appropriately monitored. The monitoring of horizontal and vertical movements, piezometric levels, and seepage quantity is normally required. Settlement of both the foundation and the embankment may need to be monitored to detect differential movement. All surface monuments should be buried deep enough that they will not be affected by freeze/thaw. Pool levels should be tracked for correlation with seepage.

Any potential outflow locations from the underground mine should be located and the outflow monitored for unexplained changes in flow quantity or appearance which could be an indication of a problem. All data should be plotted together, versus time, to allow trends in the data, and any indications of the development of an unsafe condition, to be identified and further investigated. Data should be plotted and evaluated in a timely manner by an engineer who is familiar with the site conditions so that appropriate action can be taken.

Evaluation of Breakthrough Potential: In designing an impoundment, the potential for a breakthrough of the impoundment into any nearby existing or future mine workings needs to be investigated. Several incidents have occurred where impoundments have broken into mine workings. Such events can directly jeopardize the safety of miners, and in either active or abandoned mines the inflow can pass through the mine and discharge onto the surface, endangering the general public and contaminating water supplies. The loss of settled fines from the impoundment can also lead to instability of a dam built using upstream construction.

Impoundment plans need to show that: any mine workings that could impact the impoundment have been accurately located; the nature of the overburden separating the impoundment and the mine workings has been adequately investigated; all potential breakthrough failure modes have been evaluated; and adequate factors of safety against each potential breakthrough mode have been provided. Where necessary, positive breakthrough-prevention measures need to be incorporated, with all supporting engineering analyses included in the plan. The minimum requirements for the features to be constructed to prevent a breakthrough should be detailed in the specifications section of the plan.

Potential Breakthrough Failure Mechanisms: There are several potential failure mechanisms that are associated with breakthroughs. These include sinkhole development, pillar crushing, pillar punching, internal erosion, outcrop barrier failure, and bulkhead failure. The information provided above on these topics, relative to determining potential impacts of mining on an embankment, also applies relative to breakthrough evaluations. Outcrop barriers and bulkheads are discussed below. Where slurry has been disposed of in the underground workings, the impact of the water and slurry on the potential failure mechanisms should be considered. Plans need to include evaluations of the applicable failure modes, along with substantiation of dimensions, pressures, permeability, strengths, and engineering analyses.

If the level of an impoundment rises above an area where mining has occurred near an outcrop, then the potential for failure of both the outcrop barrier, and the overburden above the outcrop barrier, should be evaluated. Besides the development of a sinkhole or internal erosion, a potential failure mode is by shearing or punching of the barrier. That is, the pressure from the water and/or slurry in the impoundment may be high enough to overcome the shear strength that is holding in place the "plug" of material separating the impoundment from the mine works. Failure could occur through the coal seam itself, through the strata above the coal (especially as this strata, on the diagonal, may represent the shortest distance between the impoundment and the mine entry, and this strata may be highly weathered), or along the interface of different materials or discontinuities.

Cases may arise where a bulkhead is constructed in a mine opening to prevent a breakthrough into the mine. Bulkheads can fail when the pressure acting on them causes the bending or shear strength of the bulkhead material, or the strength of the anchorage, to be exceeded. Bulkheads can also fail from seepage eroding or weakening the immediate surrounding strata. Plans need to include structural evaluations of bulkheads and their anchorage, and need to address the measures to be taken, normally grouting, to prevent seepage from causing failure of the surrounding strata.

In breakthrough evaluations, an additional consideration, when there are auger holes or highwall mining entries, is whether a breakthrough can occur through the coal left at the end of such openings, or as a result of the collapse of these openings. Also, the thin webs of coal between the openings may be marginally stable, and may collapse and cause ground deformations that could lead to a breakthrough.

Basin Design Measures to Prevent Breakthroughs: If, considering the level of uncertainty about the information, the margin of safety against a breakthrough is considered inadequate, then an alternative site should be found or compensating or remedial measures should be designed. Prevention measures could include some combination of the following: providing a "safety zone" around the impoundment; providing support by backfilling portions of the mine; improving the in-situ materials by grouting; constructing an engineered barrier; isolating the reservoir from the area of influence of the mining; strengthening the fines (slurry impoundment); constructing secondary defense measures, such as bulkheads, to contain a breakthrough within the mine or a section of the mine; and other engineered measures that would control seepage and reduce pressures in the areas of potential breakthroughs. Whichever methods are used, the geometries, engineering properties, engineering analyses and construction specifications, must be fully substantiated and documented in the plan. Plans should include requirements that the construction of critical breakthrough prevention measures be examined and accepted by an engineer who is familiar with the plan requirements, preferably a representative of the designer.

A design measure that has been used in breakthrough potential situations is to construct a barrier of compacted fill around the inside of the reservoir area. A fill barrier can provide additional bulk between the impoundment and the mine workings, and, when provided with properly designed internal drainage, can lower the water pressure against the outcrop barrier. Compacted earthen barriers can be placed to keep the impoundment pool from ever being above, or within a draw angle of, the mine workings. In such cases, adequate freeboard should be provided for the

barrier based on the appropriate design storm. These barriers should be designed and built to the same type of specifications as are used for an earthen dam, and plans should provide complete design and construction details. Appropriate monitoring provisions, such as the installation of piezometers to verify design piezometric levels, should be included.

A precaution with the compacted-barrier approach is that where the thickness and characteristics of the overburden indicate the potential for the roof strata to collapse to near the surface, forming a sinkhole, construction of a surface barrier should not be considered to take the place of measures to prevent sinkhole development. That is, an approach of placing fill material on the surface above a potential sinkhole, relying on the fill to bridge over or collapse into and choke off the sinkhole, should not be used. If a sinkhole does form, there is no guarantee that the fill material above it will not be eroded into the hole and allow the impoundment to discharge into the mine.

Fine coal refuse deposited in a slurry impoundment typically has a relatively low permeability and some of the material will tend to seal the bottom of the reservoir as the fines accumulate. However, since there is typically a pool of water above the level of the settled fines, the fines should not be relied on, by themselves, to limit seepage into a compacted barrier. More positive means of primary seepage control should be provided, such as a compacted impervious liner and/or an internal drainage system.

Whether settled fines will flow in a breakthrough situation depends on such factors as its degree of consolidation and cohesive strength, the state of the pore-water pressures, the potential for excess pore-water pressures to be induced, and the size of the available opening. Designers should consider that just because a soil is shown to be at or below its liquid limit does not, in itself, demonstrate that the material will not flow. The liquid limit is simply a water content corresponding to an arbitrary boundary between the “liquid” and “plastic” states of a soil. It indicates nothing about how the soil will behave when bridging an opening with the pressure of the contents of an impoundment above it, or when excess pore-water pressures are induced. If a subsidence event occurred under saturated, hydraulically placed fines, for example, the sudden increase in shear stress in the fines would induce increases in pore-water pressure that could trigger “static liquefaction” and cause the fines to flow.

Low-density polyethylene (LDP) liners have been used as an element in breakthrough prevention measures. Such liners can provide a positive barrier between the impoundment pool and the natural hillside while not requiring the relatively large volume needed for an earthen barrier. Caution must be exercised in the use of such liners. Factors to be addressed in plans include: potential subsidence or settlement strain on the liner material; punching or tearing of the liner by equipment or sharp rocks; anchorage of the liner to prevent movement; and sealing of the liner edge area. Applicable manufacturer’s recommendations should be followed regarding the installation of liners.

The manner in which an impoundment is operated can affect the breakthrough potential. Plans should require, for example, that impoundments are designed and operated in a manner that minimizes the amount of free water in the pool. Decant raises should be staged to limit incremental rises in the pool level.

Provisions for Monitoring Breakthrough-Related Performance Parameters: Wherever the potential for a breakthrough exists, critical parameters should be identified and plans should include a monitoring program that will show whether or not the barrier and /or overburden are performing as anticipated. Monitoring may include piezometer levels, discharge rates from mine workings, discharge rates from drains, seepage quantity and appearance (especially discoloration or presence of fines) water levels in the mine and behind bulkheads, ground movement, rainfall, etc. The acceptable range and warning or action levels should be established for monitored values. Monitoring programs should include requirements to have the data plotted and evaluated in a timely manner by an engineer familiar with the design of the facility. It is good practice to plot all monitored values on the same graph to check whether the trends are reasonable over time, and to allow for unusual conditions or trends to be recognized.

Coal company personnel who routinely inspect the impoundment, or routinely work on or around the impoundment, should be trained to watch for potential signs of trouble with respect to a breakthrough. Such personnel should be aware of where underground mining has occurred and where to look for cracks or other evidence of subsidence. Other signs they should look for include unusual drops in the pool level, the presence of a whirlpool or bubbles in the pool, unusual piezometer readings, changes in the quantity or appearance of seepage, and changes in the quantity or appearance of discharges from mine openings, backfilled mine openings, and outcrops.

26. Construction Specifications and Drawings

Impoundment plans need to include complete and detailed construction specifications and drawings for the entire facility. The specifications and drawings should be sufficiently clear and detailed to allow the impoundment to be constructed in accordance with the design requirements and intentions. While construction specifications should be tailored to the conditions at each site, designers may find it useful to consult sample specifications, such as those provided in "Design of Small Dams" (1987), or similar references.

27. Construction Monitoring During Critical Phases of Construction

While it is important that all aspects of an impoundment be constructed according to the approved plan, special attention needs to be paid to critical items such as: foundation/abutment preparation; cutoff trench excavation and backfilling; installation of conduits; placement of seepage diaphragms; installation of internal drains; placement of filter layers; construction of spillway liners; establishment of upstream push-outs, and treatment of mine or auger openings. Plans may need to be modified and re-submitted for approval in response to unanticipated conditions or difficulties that do not become apparent until during the construction process. Photographs taken during construction provide valuable information for evaluating the post-construction performance of a structure and any problems that may arise.

Plans should specifically require that critical phases of construction will be monitored by a qualified engineer who is familiar with the design requirements. The minimum requirements for construction monitoring, and the items to be observed, should be included in the specifications

section of the plan. The approved plan should also identify "critical construction" activities (see page 8), and require the mine operator to notify MSHA when such 'critical construction' is to take place.

28. Instrumentation Monitoring of Impoundments

All impoundment plans should include measures for monitoring the performance of the site. Monitoring helps determine whether design features are performing as intended, and can provide early warning in the event of a problem. Instrumentation is recommended for all dams, but for sites with high or significant hazard potential, the installation of piezometers and weirs to monitor phreatic level and seepage quantities should be considered a minimum requirement. All monitoring records should be maintained for the life of the facility, as a site's performance history is helpful in determining the severity and cause of problems that may develop. Additional comments on instrumentation and monitoring follow:

A. Seepage: Seepage from the impoundment should be monitored. This includes seepage through the embankment, through any internal drainage measures, and through any underground mines that receive seepage from the impoundment. Weirs should be installed, preferably with a staff gauge in the weir's upstream pool, so that flow rates can be readily and accurately measured. If other methods are used, such as measuring flow through a pipe, then the procedure should be standardized so that all measurements, regardless of who takes them, are consistent and comparable. Preferably, the same person or persons, following the exact same procedures, takes the measurements. To evaluate seepage at or near an abutment, it is useful to have information on pool level, rainfall and groundwater levels, so that correlations can be evaluated.

   In addition to flow quantity, seepage should be monitored for changes in appearance. Discoloration, or the presence of fines carried in the discharge, may be an indication of piping or internal erosion (but be aware that for water that has flowed through mine workings, sediment may have dropped out in pools within the mine). Records should be kept on both seepage quantity and appearance, and any unusual changes in either property should be investigated.

B. Piezometric Levels: Saturation levels and water pressures within a dam, as well as within any earthen barriers, should be monitored and recorded to determine whether hydrostatic pressures are within design values, and whether the changes or trends are reasonable. Plans should include tables that show the allowable water elevation or reading in each piezometer, based on maintaining an acceptable factor of safety for stability. A copy of this information should be kept in the 7-day examination book so that the examiner can immediately check whether allowable piezometric levels are being approached or have been exceeded. Any unusual changes or trends in piezometer data should be investigated.

   It is good practice to use piezometers that isolate a zone in which the water pressure is to be monitored, versus using an "observation well." The disadvantage of an "observation well" is that the measured water level represents the contribution from all layers intersected by the borehole. Thus, it is not possible to distinguish between water pressures occurring at different elevations throughout the borehole, as can be done with a properly designed open-standpipe piezometer, or a closed-system piezometer. In

situations where it is critical to be able to measure a rapid or sudden change in pore water pressure, a closed system, such as a vibrating-wire piezometer, should be used.

C. Pool Levels: Records should be maintained for the pool level in the impoundment so that correlations can be checked with piezometric levels and seepage quantities. Where water in nearby mine workings has the potential to affect an impoundment or to indicate the performance of a barrier, the mine pool level should be monitored.

D. Rainfall Data: It is good practice to install a rain gauge at an impoundment, but it is especially important in situations where there is breakthrough potential and discharges from a mine are related to seepage from the impoundment. Rainfall data should be routinely collected and recorded in such cases so that it can be determined whether changes in seepage, mine discharge, or water level data correlate to rainfall infiltration/runoff, or may be occurring for other reasons.

E. Deformation or Movement: Where significant embankment settlement can occur, or the potential for subsidence exists in the vicinity of an impoundment, movement should be monitored and recorded. Where subsidence is a concern, both horizontal and vertical movement should be measured. Movement should also be monitored if evidence of slope movement is detected. In any situation where deformation is occurring, the rate of movement, especially acceleration of the rate, provides valuable information for assessing the seriousness of the situation. Methods to monitor surface deformation include survey monuments and extensometers. Movement with depth can be monitored with inclinometers and extensometers. Surface monuments should be installed deep enough that they are not affected by freeze-thaw action.

The type and frequency of monitoring that is prudent depends on the particular conditions involved at each impoundment. Monitoring is performed during the inspections that qualified company personnel are required to make, per MSHA regulation, typically on a seven-day basis. Where conditions warrant, more frequent, or even automated continuous monitoring should be performed.

Monitoring data is meaningless if it is not plotted and analyzed in a timely manner by a person who is knowledgeable about the significance of the information. Plotting allows trends in the data to be evaluated. It is useful to maintain plots of all related data on the same graph, and over the same time period, to allow the data trends to be effectively compared. The minimum requirements for the installation and monitoring of instrumentation, including plotting and evaluating the data, should be included in the specifications section of the plan.

29. Fine Waste Disposal in Cells

Some mining companies use a system of "cells" for the disposal of fine coal waste. The fines may be in the form of slurry, or filter cake that is too wet to compact in layers. In cells, fine waste is disposed of in relatively shallow layers that are then covered with coarse coal refuse, allowing the fines to drain and consolidate in a relatively short time. Most of the same design

considerations that apply to a traditional impoundment also apply to a cell facility. These include: a geotechnical investigation to determine embankment and foundation characteristics; testing for relevant material properties, including shear strength; static and seismic slope stability analyses; underdrains to control the phreatic level; a breach analysis, unless the hazard potential is otherwise apparent, to determine the appropriate hazard-potential rating and design storm; monitoring devices to confirm design assumptions; construction specifications; and construction monitoring.

It has been common practice to design a "structural shell" as the downstream containment structure for cells. The structural shell is designed much in the same manner as an embankment dam with the required width, slopes, benches, internal drainage system, compaction specifications, and embankment-material strengths, to achieve acceptable safety factors for slope stability. Slurry cells work most efficiently when the depth of fines in the cells is kept relatively shallow, preferably to five feet or less. At this depth, the fines can usually drain and dry out enough that they can be efficiently covered with coarse refuse.

Slurry cells can usually be designed and constructed to mitigate breakthrough potential into underground mine works, and, for preparation plants which normally produce combined refuse, cells can provide for emergency disposal of thickener sludge. Close planning and supervision is needed to ensure that cells are constructed, filled, and backfilled in the proper sequence to make the system work as intended.

30. Emergency Action Plans (EAP)

To be consistent with current, prudent engineering practice and the Federal Guidelines for Dam Safety, the owners of high and significant-hazard potential impoundments should develop and maintain an emergency action plan (EAP). As indicated in the Federal Guidelines for Dam Safety (FEMA 64), an EAP identifies potential emergency conditions at a dam and specifies pre-planned actions to be followed before a dam fails to minimize property damage and loss of life. The EAP specifies actions the dam owner should take to moderate or alleviate the problems at the dam. It contains procedures and information to assist the dam owner in issuing early warning and notification messages to responsible downstream emergency management authorities if there is an emergency situation. It also contains inundation maps to show the emergency management authorities the areas that could be affected in case of an emergency.

An EAP should include breach and flood-routing analyses to delineate the areas that would likely be affected in the event of a release from the impoundment. A hypothetical dam failure, as well as a release through underground workings where conditions warrant, should be modeled. Breach analyses should be performed using conservative parameters for the size and time for development of the breach.

31. Fines Recovery Operations

If fines are to be recovered from a slurry impoundment, any potential impacts on the safety of the impoundment should be addressed in a plan. The plan should explain any impacts on outlet works and how the design storm will be handled during the operation. If there is upstream

construction, or barriers built over slurry related to mine workings, removal of fines could remove support. In such cases, an analysis should be performed to show how close to the upstream slope, or to the barrier, the fines recovery can take place without compromising the stability of the embankment or the barrier.

32. Provisions for Impoundment Abandonment

As per 30 CFR 77.216-2(a)(16), impoundment plans are required to include "general provisions for abandonment." As a minimum, general provisions and concepts for how the impoundment will be abandoned at the end of the last proposed stage, or when the impoundment is no longer needed, should be included in the impoundment plan. It should be noted that this requirement is separate from, and in addition to, the requirement in 30 CFR 77.216-5 to obtain an approved abandonment plan.

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APPENDIX A: Memorandum

U.S. Department of Labor

Mine Safety and Health Administration
1100 Wilson Boulevard
Arlington, Virginia 22209-3939

JAN - 7 2003

CMS&H Memo No. HQ-03-003-A (OSV 5-11)

MEMORANDUM FOR: LINDA ZEILER
JOSEPH PAVLOVICH
ALVIN BROWN
ROGER SCHMIDT
CHARLES GRACE
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HAROLD OWENS
JOHN FREDLAND
ALVAH L. SKAGGS
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JAY MATTOS

FROM: RAY McKINNEY
Administrator for
Coal Mine Safety and Health

MARK E. SKILES
Director of Technical Support

GEORGE FESAK
Director of Program Evaluation and
Information Resources

SUBJECT: Selection of Personnel to Participate in Updating the Impoundment Inspection Handbook

Subsequent to the 2000 breakthrough at Martin County Coal Corporation's Big Branch Slurry Impoundment, it has been determined that a reassessment of the Agency's policies and procedures concerning impoundment plan approvals and inspections is necessary. Therefore, you have been selected to participate in the committee to assess information for incorporation into an updated Impoundment Inspection Handbook.

The committee will be assigned to incorporate some of these specific items into the handbook:

A. Review all previously issued directives concerning impoundments and determine which are still applicable.
B. Review all existing PPLs, PILs, PIBs, and memoranda of instruction concerning impoundments and determine which are still applicable.
C. Develop a uniform rating system in order to differentiate levels of impoundment plan complexity.
D. Study the development of guidelines to be utilized by plan approval personnel to ensure accurate location of mine workings under or near an impoundment (i.e., additional surveying, requiring drilling, etc.).
E. Develop national guidelines and inspection frequency timetables for the inspection of impoundments: during construction phases; with high, moderate, and low hazard classifications; or, with varying degrees of breakthrough potential.
F. Develop national guidelines and inspection frequency timetables for the inspection of impoundments where these are ancillary to closed/abandoned mines.
G. Establish timeframes in which to complete the plan approval process at both the district and Technical Support offices.
H. Pending the receipt of findings of the Assistant Secretary's Joint Committee evaluating the Peer Review, recommendations concerning directives or guidelines relating to inspections or plan reviews will also be incorporated into the updated Impoundment Inspection Handbook.

Please develop a time line and action plan for completion of this project and submit it to each of us by February 24, 2003.

You will be contacted by Linda Zeiler or Joseph Pavlovich; co-chairpersons for this committee, with information regarding the first scheduled meeting date.

If you have any questions or comments, please contact either one of the above-referenced individuals.

APPENDIX B: IRPI – Summary of Input Information

Appendix B - Impoundment and Refuse Pile Inventory – Summary of Input Information

The following is an explanation of the impoundment-related information to be input into the IRPI. The IRPI input screen is accessed through MSIS, and the fields listed below are displayed. The information is typed into the appropriate block or selected from a drop-down box. Items with an asterisk are "required fields" that must be filled in before the information can be saved - other fields can be left blank if the information is not available.

The information for the IRPI should be obtained from approved plans, annual reports, district records, field inspection notes, and the Impoundment Data Sheet. Note that for impoundments under construction, the information in the IRPI is intended to reflect the impoundment conditions that actually exist in the field at the time the data is updated (or the last known or reported conditions), not the conditions for which the impoundment is approved to be constructed.

1.	Structure type*	Select "impoundment" (versus "refuse pile").
2.	State/County *	Select the state and county in which the impoundment is located from drop-down boxes.
3.	Structure name*	Type in the official name of the impoundment. Do not abbreviate unless it is part of the official name.
4.	Structure ID #*	Enter the MSHA impoundment ID number in the format of STDTNNNNN-NN (e.g. PA0200107-04).
5.	ID Issue date	Enter the date the MSHA impoundment ID number was issued; use the format mm/dd/yyyy (e.g. 04/01/2001).
6.	Phase	Select either "under construction" or "construction completed" from the drop-down box.
7.	Status*	Select "Active," "Abandoned," or "Orphaned."
8.	Stage	Enter the designation for the present stage.
9.	Nearest Downstream City/Town	Enter the name of the first city/town that would be affected in the event the impoundment failed.
10.	Distance to Nearest Downstream City/Town (mi.)	Enter the distance to the nearest mile (and tenths of a mile, if appropriate).
11.	Latitude*	Enter the latitude at the dam centerline as a single value in decimal degrees, i.e., Degrees + (Minutes/60) + (Seconds/3600).
12.	Longitude*	Enter the longitude at the dam centerline as a single negative value in decimal degrees, i.e., Degrees + (Minutes /60) + (Seconds/3600).
13.	Structure is located	Select either "on a river or stream," "on an unnamed tributary," or "offstream" from the drop-down box.
14.	Dam Owner Name	Enter the name of the impoundment owner, normally the mine operator.

15.	River or Stream	Enter the name of the stream or river that the impoundment is located on, or that the drainage from the impoundment is tributary to.
16.	Section/Range/Township	Enter this information, if applicable, in whatever form is used locally.
17.	Emergency Action Plan*	An EAP is defined, for the purpose of this database, as a plan of action to be taken to reduce the potential for property damage and loss of life in the area that would be affected by failure of the impoundment. Note that standard 77.216-4 requires mine operators to have "procedures for evacuating coal miners from coal mine property which may be affected by the hazardous condition." However, the Federal Guidelines for Dam Safety call for EAPs to apply to everyone who may be affected, i.e., miners and non-miners, and persons both on and off mine property. MSHA encourages all owners of high and significant hazard impoundments to develop and maintain an EAP that meets the Federal Guidelines. Some States require EAPs. For the purpose of this inventory, select "Yes" if you know there is an EAP for the impoundment that includes provisions to notify the downstream public and includes an inundation map that delineates, based on a dam-breach flooding analysis, the areas that are expected to be flooded in the event of a failure. Select "No" if you know that the impoundment does not have such an EAP. If you do not know whether the impoundment has an EAP that meets the above definition, select the third alternative, "Not Required" (which, for the purpose of this database, signifies "Not Known"). These selections will assist MSHA in tracking how many sites have EAPs of the type called for in the Federal Guidelines.
18.	Other Structure Names	Enter any other impoundment names in common use.
19.	Purposes	Select from drop-down box. Use "Tailings" for slurry impoundments. Use "Sedimentation" only for erosion control impoundments. Indicate as many intended purposes as apply.
20.	Structure Designers	Enter the name of the principal company that designed the impoundment first; then add the names of companies who designed modifications.
21.	Modifications – Year	Enter the year that construction of the modification was completed.
22.	Modifications – Type	Select the type of modification from the drop down box, i.e. structural, foundation, mechanical, seismic, hydraulic, or other.

23.	Certification Due Date	Enter the due date of the annual impoundment certification in 77.216-4. Use the format mm/dd/yyyy.
24.	Certification Received Date	Enter the date the last annual impoundment certification was received, in format mm/dd/yyyy.
25.	Company Contact	Enter the name of the person who is the company's lead contact for the impoundment.
26.	Company Phone Number	Enter the area code and phone number of the lead contact.
27.	MSHA Contact	Enter the name of the Supervisor for impoundments.
28.	MSHA Contact Phone #	Enter the Supervisor's area code and phone number.
29.	Inspection Frequency	The correct value will be automatically entered from MSIS. No entry is required. (This item refers to MSHA's mandatory inspection frequency based on whether the impoundment is associated with an underground or a surface mine.)
30.	# Inspections Performed This Year	No entry is required. The number of inspections will be automatically entered from MSIS.
31.	Last Inspection Date	No entry is required. The last inspection date will be automatically entered from MSIS.
32.	State Regulatory Agency	Enter the name of the state agency responsible for regulation (permitting) of the impoundment.
33.	NID	This item refers to the unique "National Inventory of Dams" identification number assigned to the impoundment. MSHA does not assign this number and it should not be confused with the mine or impoundment ID number. The NID number is normally assigned by a State dam safety coordinator. Enter the NID identification number, if known. The first two characters are the state two-letter abbreviation and the last five characters are a unique assigned number. If the NID number is not known, or has not yet been assigned, leave blank.
34.	State Regulated*	Select "Yes" or "No" to indicate whether the state regulates the site (i.e., inspects or requires a permit).
35.	Foundation Type	Select the type from the drop-down box: i.e. rock; rock and soil; soil; or unknown.
36.	Foundation Certainty	Select "known" or "unknown" from drop-down box.
37.	Core Type	Select from drop-down box, i.e. earth, plastic, etc.
38.	Core Position	Select position from drop-down box, i.e. upstream facing, homogeneous, core, or unknown.
39.	Core Certainty	Select "known" or "estimated" from drop-down box.
40.	Type of Construction	Select upstream, downstream, or centerline from the drop-down. Use "downstream" for conventionally constructed earthen dams.

41.	Dam Length (feet)	Enter the length along the crest of the dam, in feet. The length includes a spillway adjacent to the embankment. If a dam or stage is under construction, list the last known or reported length.
42.	Structure Height* (feet)	Enter the height of the impounding structure, in feet to the nearest foot. For this entry, the height is defined as the vertical distance between the lowest point on the crest of the dam and the lowest point within the dam's footprint in the original streambed or valley bottom. If a dam or stage is under construction, list the last known or reported height based on this definition. (Note that the dam height reported here, based on the downstream toe, differs from, and should not be confused with, the size criteria used in 30 CFR 77.216(a) – which is based on the upstream toe and is used to determine whether an impoundment is required to have an approved plan.)
43.	Open Channel Spillway Type	Select from the choices in the drop-down box.
44.	Open Channel Spillway Width (ft.)	Enter the width of the open channel spillway, to the nearest foot. Report as the width available for discharge when the reservoir is at its maximum designed water surface level for the current spillway. Leave blank if there is no open channel spillway.
45.	Maximum Storage* (ac.-ft.)	Enter, in acre-feet (ac.-ft.), the maximum storage, which is defined as the maximum total storage space in the reservoir at the maximum attainable water level for the current crest elevation. For slurry impoundments, the volume occupied by settled fines should be included. For impoundments under construction, or for multiple stage structures, report the last known or last reported maximum storage, based on this definition.
46.	Normal Storage (ac.-ft.)	Enter, in acre-feet, the normal storage for the current allowable normal pool level. This is defined as the total storage volume in the reservoir below the normal retention level, including dead and inactive storage, and excluding any storm storage. For slurry impoundments, the volume occupied by settled fines is included.
47.	Maximum Discharge (cfs)	Enter the flow rate, in cubic feet per second (cfs), which is capable of being discharged when the pool is at its maximum designed water surface elevation for the spillway and/or decant currently operational. Report combined flow from spillways and decants, if applicable.
48.	Last Measured Volume (ac.-ft.)	This refers to the reservoir volume and will normally be obtained from the volume reported in the last annual report under 77.216-4(a) (5).

49.	Drainage Area (sq. mi.)	Enter, in square miles, the drainage area for the impoundment, i.e. the size of the area that contributes runoff to the impoundment. For multiple stage impoundments, indicate the last known or reported drainage area. One square mile equals 640 acres.
50.	Surface Area (acres)	Enter, in acres, the surface area of impoundment at the current normal pool level. Normal pool is the level controlled by a decant or spillway or the highest allowable normal pool level for the stage. For sites under construction, or for multiple stage impoundments, report the last known or reported surface area at normal pool.
51.	Decant Pipe Type	Select from the drop-down box.
52.	Decant Pipe Diameter (in.)	Enter the inside diameter of the pipe, in inches. If the riser and transport sections have different diameters, list the transport section diameter.
53.	Year Completed	Enter the year that construction was completed on the impounding structure that was approved in the original plan approval. Leave blank if the originally approved dam is still under construction. For dams constructed and then later raised by modifications to the plan, list the year construction was completed on the original approval here, and list the years the modifications were completed under item 21.
54.	Mining Underneath	Select Yes or No from the drop-down box to indicate whether there is mining underneath or adjacent to the impoundment.
55.	Downstream Hazard Potential	Select from the drop-down box whether the impoundment is classified as having High, Significant, or Low hazard potential in the event of a failure.

APPENDIX C: Impoundment Inspection Form

Impoundment Inspection Form

Water, Sediment, or Slurry Impoundments

Inspector's Name:	Date:	Event No.
Inspector AR No.	Site I.D. No	Mine ID
Site Name:	Operator's Name:	
Mine Name	Hazard Potential Classification: **High** **Significant** **Low**	

Check the appropriate box below. Provide comments when appropriate. If not applicable, record "N/A". Any other areas that should be brought to the attention of the impoundment specialist should be noted in the comments section.

	Yes	No		Yes	No
1. Are impoundment examinations recorded?	X		20. Sloughing or bulging on slopes?		X
2. Are results of compaction tests being recorded? (operator records)	X		21. Major erosion problems?		X
3. Pool elevation? (from operator records)	1000 Feet		22. Decant Pipes:		
4. Decant inlet elevation? (from operator records)	1010 Feet		Is water entering inlet, but not exiting outlet?		X
5. Open-channel spillway inlet elev.? (operator records)	1025 Feet		Is water exiting outlet, but not entering inlet?		X
6. Lowest dam crest elevation? (operator records)	1035 Feet		Is water exiting outlet flowing clear?	X	
7. If instrumentation is present, are all required readings recorded ? (operator records)	X		23. Seepage: (specify location, appearance (e.g. clear, muddy, etc.), and approximate flow rate in comments below).		
8. What is the present construction stage(s)?			From underdrain?	X	
9. Foundation preparation performed (i.e. removal of vegetation, stumps, topsoil)?	X		At isolated points on embankment slopes or along the outside of a decant pipe?		X
10. Lift thickness according to the approved plan?	X		From natural hillside downstream of embankment ?		X
11. Cracks or scarps on crest?	X		Over widespread areas on downstream slope?		X
12. Is water impounded against upstream slope? (slurry impoundments)		X	From downstream foundation area?		X
13. Are decant trashracks clear and in place?	X		Are there "boils" beneath stream or ponded water?		X
14. Depressions or sinkholes in slurry surface, or eddies or whirlpools in the pool?		X	24. Surface movements in valley bottom or on hillside?		X
15. Are pumps used to remove water from impoundment?		X	25. Water impounded against downstream toe?		X
16. Clogged spillways, groin or diversion ditches?		X	26. Breakthrough-potential related observations:		
17. Are spillway or ditch linings deteriorated or damaged?		X	Are underground mines adjacent to or beneath the pool or embankment?		
18. Are outlets of decant or underdrains blocked?		X	Any signs of subsidence in the area?		
19. Cracks or scarps on slopes?		X	Are water flows monitored from mine openings?		

Major adverse changes in these items could cause instability and should be reported to the District Manager for further evaluation. Adverse conditions noted in these items should normally be described (extent, location, volume, etc.) in the space below and on the back of this sheet. Note that use of the terms "left" and "right" in reference to a dam should be based on facing downstream.

Inspection Issue # Comments

4 - A 1" wide by 10' long crack was observed 200ft from left abutment perpendicular to the crest.

Impoundment Inspection Form

Water, Sediment, or Slurry Impoundments

Inspector's Name:	Date:	Event No.
Inspector AR No.	Site I.D. No	Mine I.D.:
Site Name:	Operator's Name:	
Mine Name	Hazard Potential Classification: **High** **Significant** **Low**	

Check the appropriate box below. Provide comments when appropriate. If not applicable, record "N/A". Any other areas that should be brought to the attention of the impoundment specialist should be noted in the comments section.

	Yes	No		Yes	No
1. Examinations Recorded?			20. Sloughing or bulging on slopes?		
2. Are results of compaction tests being recorded? (operator records)?			21. Major erosion or deterioration problems?		
3. Pool elevation (operator records)?			22. Decant Pipes:		
4. Decant inlet elevation (operator records)?			Is water entering inlet, but not exiting outlet?		
5. Open channel spillway invert elevation (operator records)?			Is water exiting outlet, but not entering inlet?		
6. Lowest dam crest elevation (operator records)?			Is water exiting outlet flowing clear?		
7. If instrumentation is present, are all required readings recorded (operator records)?			23. Seepage (specify location, color, and approximate volume below)?		
8. What is the present construction stage(s)?			From underdrain?		
9. Foundation preparation (removal of vegetation, stumps, topsoil)?			At isolated points on embankment slopes?		
10. Lift thickness according to the approved plan?			At natural hillside in the embankment area?		
11. Cracks or scarps on crest?			Over widespread areas?		
12. Is water impounded against upstream slope? (slurry impoundments)			From downstream foundation area?		
13. Are decant trashracks clear and in place?			"Boils" downstream?		
14. Depressions or sinkholes in slurry surface?			24. Surface movements in valley bottom or on hillside?		
15. Are pumps used to remove water from impoundment?			25. Water impounded against downstream toe?		
16. Clogged spillways, groin or diversion ditches?			26. Breakthrough observations:		
17. Are spillway or ditch linings deteriorated?			Are underground mines adjacent to or beneath the pool or embankment?		
18. Are outlets of decant or underdrains blocked?			Any signs of subsidence in the area?		
19. Cracks or scarps on slopes?			Are water flows monitored from mine openings?		

Major adverse changes in these items could cause instability and should be reported to the District Manager for further evaluation. Adverse conditions noted in these items should normally be described (extent, location, volume, etc.) in the space below and on the back of this sheet.

Inspection Issue # Comments