# Chapter 11

# CONSTRUCTION AND DISPOSAL OPERATIONS

The preparation of clear and concise construction drawings, specifications and an operation and maintenance plan to guide contractors and mine personnel is an essential part of coal refuse facility development and operation. Property procurement, selection of hauling and transport equipment, determination of haul road locations, determination of refuse disposal procedures, and scheduling of construction for the various facility components are among the first steps of coal refuse disposal facility planning. These planning steps must reflect long-term operational needs as well as short-term start-up requirements.

Communication of this information to the personnel responsible for implementing the plans is essential for effective operations. A basic understanding of the general design concepts and potential safety hazards associated with a disposal facility will increase the likelihood that a program of monitoring and construction control will be conscientiously followed. Regular monitoring and on-site testing will facilitate construction and refuse disposal. Monitoring data related to disposal facility development will aid in compliance with regulatory agency requirements and will facilitate modifications to facility development should changes occur in mine production. Table 11.1 presents a summary of refuse facility operational considerations and related sections in this Manual, as well as references by other authors.

## 11.1 OPERATIONAL PLANS AND CONSTRUCTION DOCUMENTS

Constructing and operating a coal refuse disposal facility in accordance with regulatory requirements while meeting the mine's operational needs requires careful development of construction plans, specifications and an operation and maintenance plan. Development of these construction documents requires that the designer collect, interpret and analyze data related to design requirements, regulatory requirements, site conditions and the mine's operational needs. Input from the mine operator is critical throughout the design and permitting process so that mine refuse production, particularly start-up rates, are accommodated. Important aspects of refuse disposal facility design should be documented in a design report accompanying the construction documents. This report should present the rationale for facility design, important assumptions and constraints, and engineering calculations supporting facility design.

The plans and specifications should provide essential information and should be organized and presented in such a way that they can be easily interpreted by mine personnel, contractors, regulatory agencies, and monitoring personnel. The operation and maintenance plan should provide important

TABLE 11.1 REFUSE DISPOSAL OPERATIONS

| Operational Considerations | Manual Sections | Supplemental References |
|---|---|---|
| I. Operational Plans and Scheduling | | |
| • Determine the scope of activities | 11.1 to 11.2 | |
| • Review equipment capabilities | 11.3 to11.5 | O'Brien et al. (1996), Hartman (1992) |
| • Schedule development | 11.2 | Clough et al. (2008), Day and Benjamin (1991) |
| II. Equipment Selection and Use | | |
| • For transport of refuse from preparation plant to disposal area | 11.3 | O'Brien et al. (1996), Day and Benjamin (1991), Hartmann (1992) |
| • For spreading and compacting refuse | 11.4 | O'Brien et al. (1996), Day and Benjamin (1991), Hartmann (1992) |
| • For multiple use in related earth work activities | 11.4 | USBR (1998), Sherard et al. (1963), Church (1981) |
| III. Refuse Disposal | | |
| • Disposal as structural fill | 11.5 | USBR (1991, 1998), Sherard et al. (1963), Leonards (1962), MSHA (2007) |
| • Fine refuse disposal | 11.5 | Hartmann (1992), MSHA (2007) |
| • Combined refuse disposal | 11.5 | Hartmann (1992), MSHA (2007) |
| IV. Related Activities | | |
| • Haul road construction and maintenance | 11.6 | Leonards (1962), Oglesby and Hicks (1982) |
| • Liner systems (if required) | 11.6 | USBR (1998) |
| • Embankment foundation preparation | 11.6 | Sherard et al. (1963), USBR (1998), Leonards (1962) |
| • Control of water | 11.6 | USBR (1998) |
| • General excavation | 11.6 | Sherard et al. (1963), Day and Benjamin (1991), O'Brien et al. (1996) |
| • Placement of earth borrow as structural fill | 11.6 | Sherard et al. (1963), USBR (1998) |
| V. Materials Selection for Facility Appurtenances | | |
| • Filters and drains | 11.7 | MSHA (2007) |
| • Culverts and decants | 11.7 | MSHA (2007), FEMA (2005a) |
| • Concrete structures | 11.7 | USBR (1987a) |
| • Gates, valves and other metal works | 11.7 | USBR (1987a) |
| • Mine opening and auger-hole seals and drains | 11.7 | MSHA (2007) |
| VI. Quality Control and Field Testing | | |
| • Testing of compacted earth and refuse fill | 11.8 | USBR (1998), Leonards (1962), Sherard et al. (1963) |
| • Materials testing | 11.8 | USBR (1998), USBR (1991) |

information in a concise and easily understandable format so that it can quickly be used as an efficient reference guide for mine personnel performing construction and conducting construction and performance monitoring activities.

Ambiguous details, terms and statements in the specifications and drawings should be avoided. The extent of information and details provided in the plans and specifications will vary depending upon the size and complexity of the refuse disposal facility. The following sections of this chapter present guidance as to the content that should be provided in plan drawings, specifications and operation and maintenance plans for refuse disposal facilities.

An expansion or modification plan is sometimes prepared for an existing coal refuse disposal facility to address changes in facility construction associated with revisions to production rates or changed design criteria. Such plans typically include construction drawings, specifications, and a design report with supporting engineering calculations. For expansion or modification plans, it is important that an index of drawings citing all remaining original and new plan drawings be provided. Revised drawings should clearly reference appropriate specifications, and a revised set of specifications should be included in the associated submittals. If facility drawings are modified or revised as part of the new submission, it is recommended that a current index and cover sheet be prepared with a complete set of drawings to prevent confusion during subsequent review and construction.

### 11.1.1 Design Report

The design report should present the background data upon which the design is based, along with critical aspects of the design related to construction, operation, and abandonment. The design report generally includes a discussion of the following:

- Project requirements (disposal facility requirements such as refuse generation rates and anticipated life of mine)
- Existing conditions and history of the site including general geologic setting, environmental setting (wetlands, streams or other sensitive areas) previous mining activities, and climate/weather
- Field investigations such as surficial reconnaissance and geotechnical and environmental explorations
- Laboratory testing of refuse, water, soil, rock, geosynthetic materials, and structural materials
- Geologic and geotechnical site conditions, including assessment of impact of previous and planned mining activities
- Site limitations based upon reconnaissance, explorations and testing results
- Facility development and staging
- Special considerations (e.g., amendments, liner systems, mine bulkheads and barriers, construction issues such as dewatering)
- Equipment considerations (e.g., pumping equipment if needed for meeting impoundment drawdown requirements, equipment for spreading and compaction consistent with coal refuse production when conveyor systems are employed for hauling)
- Geotechnical engineering analyses including slope stability, settlement and seepage analyses (and pillar stability and subsidence analyses if underground mining is a factor)
- Hydrologic and hydraulic analyses (including design storm, dam breach and inundation mapping) and hydraulic structure design

- Structural design and detailed monitoring provisions for buried pipelines and inlet structures
- Environmental issues
- Abandonment requirements
- Monitoring and maintenance requirements (schedules for implementation and maximum recommended readings for instrumentation)
- Design recommendations and limitations

### 11.1.2 Construction Drawings

Construction drawings for a coal refuse disposal facility are probably the most important component of the construction documents. Construction drawings will likely be referred to more often by mine personnel, inspectors, engineers and regulatory agencies than any other construction documents. Accurate and detailed depiction of refuse facility design will clearly indicate the intent of the design and will facilitate construction of the facility. Construction drawings must provide information as required in 30 CFR § 77.215 and 77.216 and must satisfy applicable state regulatory agency requirements. 30 CFR § 77.216 also indicates specific information that must be presented, including the locations of surface and underground coal mine workings and the depth and extent of such workings within a distance of 500 feet from the perimeter of the facility. Construction drawings generally show initial site development and intermediate construction steps with enlargements or details of critical construction features and delineation of dimensions and materials. The following sections provide guidance as to the type of information and level of detail that should be provided on construction drawings.

#### 11.1.2.1 Title Sheet and Existing Conditions Plans

Construction drawings should include a Title Sheet listing drawings and other project and site reference information. A plan showing existing conditions at the site should be prepared, and each refuse facility structure should be identified on an USGS 7.5-minute or 15-minute topographic quadrangle map as a general location reference. This is a requirement for all impounding facilities per 30 CFR § 77.216. Plan drawings depicting existing conditions at a proposed refuse disposal site should generally be prepared at a scale of 1 inch = 100 feet (state regulatory requirements may be more stringent). Alternate scales (either smaller or larger) may be appropriate provided that existing features can be accurately located and represented and regulatory requirements are satisfied. Existing conditions plans should provide coverage of the proposed refuse disposal area and support areas and an additional 500-foot-wide area around the perimeter of the site.

In general, existing features that impact site development and construction of the refuse disposal facility should be shown on existing conditions plans. The following guideline describes the general level and type of information that should be included:

- Topographic contours of existing ground surface at 5-foot intervals or less (contours at 10-foot intervals may be appropriate for steep slopes)
- Footprint of proposed refuse facility for all proposed embankment stages
- Existing and proposed new underground mine workings within 500 feet from the perimeter of the proposed facility
- Extent and location of spoil piles and surface, auger, or highwall mining beneath the dam and impoundment areas
- Location of coal seam outcrops
- Reported geologic features or observed structures (e.g., joints, hillseams, etc.)
- Surface and subsurface utilities
- Existing refuse disposal facilities

- Property boundaries
- Prospective borrow areas
- Existing dams and embankments
- Delineation of forests/woods and heavy vegetation
- Existing buildings and structures
- Oil, gas and water wells (active and abandoned)
- Watershed limits, streams and wetlands
- Springs, seeps and mine discharges
- Landslide areas, mine subsidence features, and other ground disturbance
- Exploratory boring and test pit locations
- Public roads and mine access/haul roads
- Mine shafts, boreholes, vent holes and other mine openings
- Other identifiable natural or man-made features (e.g., cemeteries, buildings, etc.) that could affect the operation of the refuse facility

#### 11.1.2.2 Initial Site Development Plans

As explained throughout this Manual, extensive site development may be required for preparing a site to receive coal refuse material. To provide a stable embankment foundation and safe working area for the placement of refuse and efficient operation of heavy equipment, site development construction may be necessary. The following items should be considered for presentation on initial site development plans at the same scale or larger than the existing conditions plans:

- Areas requiring clearing, grubbing and topsoil stripping
- Topsoil and excess material stockpile areas
- Utility line modifications or relocations
- Oil, gas and water well modifications or abandonment details
- Areas requiring subsurface drainage such as spring/seep collection systems and other underdrain systems
- Prospective borrow areas
- Stream diversions
- Access/haul road alignments and proposed grading contours
- Location(s) of survey control points
- Foundation and abutment areas requiring special subgrade preparations or treatment
- Barriers or backfill areas for treatment of mine openings (shafts, boreholes, auger holes, drift mine openings) or underground mine workings
- Initial erosion and sedimentation control measures
- Diversion and collection ditch alignments
- Environmental barriers or buffer zones
- Cutoff and key trench location (for impounding facilities)
- Seepage barrier locations and requirements
- General subgrade preparations including benching ("keying") requirements
- Subsurface drainage (spring, seep or stream drains)
- Limits of liner installation (clay or synthetic) if applicable per state regulations
- Decant pipe (with riser locations and elevations), principal spillway, and emergency spillway alignments

Some of the items listed above will probably require depiction with additional plans and details. To meet both operational and environmental requirements, some larger coal refuse disposal sites may need to have phased initial site development plans. These plans should be organized such that site development requirements are depicted sequentially. Sections 11.1.2.5 and 11.1.2.6 address additional drawings that may be required and the level of detail that should be provided to supplement plan view drawings.

#### 11.1.2.3 Refuse Embankment Construction Plan Views

Proper presentation of refuse embankment designs, whether for an impounding or non-impounding facility, will normally require more than one plan view drawing. As indicated in Chapter 5, coal refuse embankments are typically constructed in stages. Each stage of a coal refuse embankment should be depicted by at least one plan drawing at the same scale or smaller than used in the existing conditions or initial site development plan drawings. Detailed plan views, cross sections, profiles and larger-scale details should be used to depict the design of refuse embankments and appurtenances. The required drawings for impounding facilities (including slurry cell facilities) will generally be greater in number and detail than for non-impounding facilities. Detailed drawings of impounding facilities should normally be prepared at a scale of 1 inch = 100 feet, although a smaller scale may be appropriate for larger sites if sufficient detail is provided in cross sections and enlargements. As a guideline, the following items should be presented on embankment construction drawings:

- Footprint and limits of each embankment stage and associated haul road or conveyor belt system
- Delineation of the embankment and material zones
- Proposed topographic contours of each stage at intervals at 5 feet or less
- Footprint, grades and elevations, and flow direction of internal drains
- Collection and diversion ditch alignments, grades and elevations
- Decant pipe alignment and riser locations
- Decant riser schedule with allowable inlet elevations for each embankment stage
- Spillway location and alignment
- Drainage requirements for the working surface
- Piezometer and other instrument locations
- Tabulation of allowable phreatic surface levels measured at piezometers
- Tabulation of maximum pool level for each stage under design storm conditions
- Anticipated fine refuse level at end of each stage, especially for impounding facilities with upstream construction
- Work area sequence within each stage of construction where multiple zones of placement are specified (upstream, downstream or centerline)
- Construction items and sequence for each stage, including features such as seepage barriers, mine barriers and seals, etc.
- Haul road and conveyor belt locations and planned extensions

The plan view drawings for each construction stage should include references to cross sections and details for complex features of the design.

#### 11.1.2.4 Cross Sections and Profiles

Cross sections and profiles are normally prepared to provide details not depicted on plan views. Cross sections are very useful for delineating the various stages of facility development. Cross sections are also useful for illustrating complex features of refuse facility design such as cutoff trenches, subsurface drainage/underdrains, decant pipe installations, and subgrade preparations.

Consistent with 30 CFR § 77.216, at least two cross sections including longitudinal and lateral cross sections through the highest and lowest elevations of a refuse embankment must be provided. Additional cross sections may be needed for complex refuse embankments, especially impounding embankments. The number of additional cross sections is dependent on the complexity of the facility design and the construction required for tying into previously constructed features. The following items should be considered for inclusion on refuse embankment cross sections:

- Soil and rock units with meaningful descriptions below and at foundation grade
- Elevations and locations of any underground mines (this may require a separate cross section, as the depth to the mine workings may require too large a scale to depict other items)
- Original ground surface (and existing ground surface if different from original ground surface)
- Foundation improvements and special subgrade preparations
- General subgrade preparations
- Embankment surfaces and slopes depicting material zones, if applicable
- Upstream and downstream slope and abutment protection measures
- Delineation of each embankment stage
- Maximum and minimum crest elevations for each embankment stage
- Anticipated fine refuse level at the end of construction for each embankment stage
- For upstream stages, the approximate mixing zone of coarse and fine refuse associated with pushout and development of the embankment stage
- Maximum normal and design storm pool level for each stage
- Final surface grade upon reclamation including provisions for drainage control
- Underdrains/subsurface drainage features and internal drainage systems
- Decant pipeline and risers
- Spillways, including dimension, peak water surface elevation and erosion protection
- Terraces/benches on embankments
- Piezometer locations with sensing zone elevations
- Proposed support equipment or structures (conveyor belts, load out bins, haul roads, etc.)
- Liner systems
- Design phreatic surface
- Stability analysis results depicting subsurface conditions/properties, critical failure surfaces (circular, block and wedge surfaces) and minimum factors of safety

Profiles are useful when presenting the design of haul/access roads, decant pipe alignments, ditch alignments, and underdrains and other components that extend a great distance laterally. As a guideline, profiles should include the following information:

- Original ground surface
- Proposed/final ground surface
- Grade breaks with corresponding slope designations
- Geometry and layout data (such as radii, point of vertical intersection, etc.)
- Bedding and backfill details for pipes and spillways

- Erosion protection measures for ditches and spillways (if not shown on detailed cross sections)
- Critical subsurface soil and rock conditions and site development requirements

The scale for cross sections and profiles should be the same for both the vertical and horizontal directions, although exaggerated cross section segments may be appropriate at large sites where there is significant relief. The scale should be sufficient for clear and accurate representation of design features. If necessary, more detailed, larger-scaled cross sections should be prepared for critical facility components.

#### 11.1.2.5 Detailed Plan Views and Cross Sections

For instances when the plan view and cross-section drawings for individual stages of a facility do not convey the level of detail for critical design features desired by the designers, larger-scale plan views and cross sections should be prepared. The following are facility components or features for which detailed plan views and cross sections may be needed:

- Cutoff trench/keyway cuts, buttresses and other stabilization structures
- Subsurface drains and underdrain systems including spring/seep drains
- Soil liners and graded filters
- Collection and diversion ditches
- Terraces/benches on the refuse embankment
- Subgrade and foundation preparations
- Treatment provisions (backfill, barrier, drainage, etc.) for mine workings and openings
- Spillways
- Decant pipes and risers, including bedding/backfill zones, thrust blocks, and trashracks
- Stilling basins
- Filter diaphragms
- Haul/access roads
- Piezometers, weirs and other instrumentation
- Embankment and impoundment capping details
- Stream diversions
- Erosion and sedimentation controls
- Culverts and other piping systems

#### 11.1.2.6 Miscellaneous Details and Information

Documentation for impounding refuse disposal facilities should include a stage-area curve and a stage-volume curve for the impoundment and a stage-volume curve for the embankment. For facilities that rely on storage of all or part of the design storm runoff, notation of the maximum decant level inlet, open channel spillway inlet (if present), and the design storm volume (or portion thereof that must be stored) should be included on the appropriate curves to demonstrate that sufficient storage is available without overtopping the embankment. Additionally, the head-discharge curve for the decant and spillway should be presented, if applicable. These plotted data should be provided in the operation and maintenance plan, as discussed in Section 11.1.4.

If special construction methods or items are required, they should be detailed in the drawings. Facility components/details such as berms, pipe beddings, piezometers, V-notched weirs, staff and rain gauges, clear water cells, and sealing of mine openings may require additional drawing details and information related to their installation or construction.

### 11.1.3 Technical Specifications

A complete set of technical specifications that corresponds directly to the construction drawings should be prepared for the construction of a refuse disposal facility. Similar to the construction drawings, the level of detail required in the specifications is a function of the type and complexity of the refuse facility being constructed. At a minimum, the critical construction requirements that impact dam safety and facility operation, as cited in Section 11.2.2, should be clearly addressed in the specifications. Any information related to construction sequencing or methods that are recommendations, but not requirements, should be cited as such in appropriate locations in the plan.

There are several standardized specification systems ranging from basic to sophisticated. Specifications for refuse disposal facilities must provide sufficient detail that contractors and/or mine personnel can easily and clearly understand the facility design requirements. It is recommended that specifications follow a consistent format. The following are industry accepted standard specification systems that may be applicable and are regularly used for other civil engineering projects:

- CSI by the Construction Specifications Institute
- SPECTEXT® by the Construction Sciences Research Foundation, Inc.
- SpecsIntact by the National Aeronautics and Space Administration (NASA)

These specifications are organized in groups and/or divisions that address categories of work such as site development, earth fill, and concrete construction. Each individual specification section normally has three parts: (1) General/Scope of Work, (2) Products and (3) Execution. Appropriate specification sections to suit the needs and requirements of facility design should be chosen from the standardized specifications by the designer. Because of the specialized nature of coal refuse disposal facilities, the organization of the standardized specifications may need to be modified to suit specific construction activities and to reflect construction staging and chronological sequence requirements.

If the designer chooses not to use a standardized specification system, the format of the specifications should include at a minimum the following three parts: (1) General/Scope of Work, (2) Materials/Products, and (3) Construction Requirements/Execution. If necessary for clarification of design requirements, a fourth part titled Method of Measurements may be included. It is ultimately at the discretion of the designer as to the format of the specifications and the level of detail provided. Typically, project specifications will consist of a number of individual specifications, each of which follows the format just described. The following describes the content of each portion of a specification in the above format:

- General/Scope of Work should provide an overall description of the work and construction items covered by the specification. Details including the general construction methods and suggested or required sequence of work progression should be included. Specific construction drawings should be identified to clarify the work covered by the specification. Information concerning related specifications, applicable references, and required submittals should also be provided. It is often useful for this portion of the specification to include a technical description of the outcome or function desired by the designer for the particular section. Administrative and procedural requirements applicable to the work should also be included.
- Materials/Products should specify the requirements of the materials, products and accessories to be utilized for construction. Information such as strength, gradation, composition, and tolerances of the materials should be provided. The desired testing requirements and material certifications to be supplied by the manufacturer should also be provided in this section along with a list of submittals where the engineer's approval is required prior to construction. A listing of prospective manufacturers of

some materials may be helpful. Where possible, standardized material designations from American Association of State Highway and Transportation Officials (AASHTO), American Society for Testing Materials (ASTM), or state and federal agencies should be provided. If substitutions are allowed, it is important that sufficient information is provided to allow for equivalent substitution. Submittals to verify that the appropriate materials/products are being used by the contractor should be specified in this section.

- Construction Requirements/Execution should be detailed and should include specifics as to construction methods and, if appropriate, equipment that meets the designer's requirements. A detailed construction sequence and schedule can be provided along with a description of the final work product desired. Plan view, detail and cross-section drawings should be referenced, along with specifications for related work. When applicable, dimensions and tolerances of construction items should be provided. Oversight, inspections, quality control testing, and reporting requirements should be indicated. Lastly, requirements for inspection of critical aspects of the construction by the designer or other engineers familiar with the design requirements should be included.
- Method of Measurements can be included in a specification to facilitate work progress and to establish benchmarks for payment and scheduling. For most the construction items, methods of measurements can be established using standard measurement units such as length, area and volume. Methods and required accuracy for field measurements should be prescribed. Where unit measurements are not feasible, other performance criteria should be defined.

For a refuse facility, detailed specifications that are carefully linked to construction drawings normally provide the most complete depiction of the design and construction requirements. Each individual specification should complement and be consistent with other individual specifications that make up the total specification package for facility construction. Responsibility for permits for certain activities (e.g., burning or blasting) should be cited in the associated specification. The number of specifications required for a particular refuse facility depends upon the type and complexity of the facility design. It is the responsibility of the designer to determine the number of individual specifications needed to convey the design intent. The following is a list of specification topics that may be appropriate for a refuse disposal facility:

- Survey control and construction documentation
- Clearing, grubbing, stump removal and demolition
- Utility relocation and protection
- Well abandonment (gas and water) and mine opening sealing (boreholes, shafts, vent holes, auger holes, drifts, and slopes as well as subsidence features)
- Control of water and stream diversion
- Temporary erosion and sedimentation control
- Sediment/treatment ponds
- Excavation and earth embankment construction
- Foundation preparation
- Exploration for mine openings and sealing of coal seams (exposing coal seams to locate openings and covering coal seams with non-combustible material)
- Backfilling of underlying mine workings
- Internal drains and underdrains
- Liner system
- Culverts

- Decant pipe and principal and emergency spillways
- Conduit thrust blocks and filter diaphragms
- Stilling basins
- Collection and diversion ditches
- Haul and access roads
- Refuse disposal and construction (including placement, compaction, and testing)
- Concrete structures
- Instrumentation
- Reclamation, seeding, soil supplements and mulching

It is recommended that each set of specifications have a summary or administrative section that identifies and defines the entities (e.g., Mine Owner/Operator, Engineer, and Contractor) involved in the design, construction and operation of the refuse disposal facility and that clearly identifies the roles and responsibilities of each party throughout the construction of the facility. Items such as basic contract descriptions, work to be provided by the owner and use of the site should be included. Additionally, this section should address site safety responsibility. It is also recommended that each set of specifications be accompanied by a copy of the design report along with guidance related to construction methods and sequence of construction.

Generally, an individual familiar with the design and engineering requirements, such as the design engineer, is designated as the Engineer. Also, a representative of the Mine Owner/Operator (Operator) is also identified. Both the Engineer and Operator typically have responsibilities for monitoring, inspection, and reporting.

### 11.1.4 Operation and Maintenance Plan

An operation and maintenance plan is a guidance document recommended for use by construction and inspection/monitoring personnel during construction and operation of the facility. The intent of an operation and maintenance plan is to provide information routinely needed on a daily basis by mine personnel, contractors and inspectors/monitors for construction and operation of the facility after disposal operations have commenced. The plan should clearly identify the roles of various parties in monitoring and inspection activities and should cite the involvement of a registered Professional Engineer who is familiar with the design (including dam safety criteria) for the structure. Additionally, the representative of the Mine Owner/Operator (Operator) who is responsible for the facility and work with the Engineer should also be identified.

An operation and maintenance plan should also provide guidance regarding evaluation of conformance with the approved disposal plan and actions to be taken when observations, testing or instrumentation data identify suspected adverse conditions or obvious hazardous, unsafe or unacceptable operating conditions. It should be noted that the operation and maintenance plan is not a substitute for construction plans and specifications. A complete set of construction plans and specifications should always be readily available during construction and operation of the facility.

An operation and maintenance plan generally does not contain information related to initial site preparations and development activities, but may provide provisions for the safety of operating personnel and the facility, including the following information:

**<u>Embankment Construction</u>**

- Construction method (upstream, downstream or centerline) and upstream construction implementation procedure, if applicable

- Summary table of crest elevations for each stage
- Schedule of decant riser inlet elevations applicable for activation during each stage with the corresponding minimum required crest elevation
- Specific equipment, methods and lift thicknesses for refuse placement
- Procedures for upstream construction and allowable pore pressure readings during upstream pushouts
- General grading requirements and slopes for embankment outslopes, working surface, benches and haul/access roads
- Reclamation schedule with general capping information
- Monitoring frequency for refuse generation rates for comparison to rates used for facility design
- Survey control and monitoring frequencies
- Decant pipe deflection monitoring

**Handling, Spreading and Compaction Equipment Criteria**

- Recommendations and criteria for hauling equipment based upon refuse generation rates as provided by the operator or owner
- Recommendations and criteria for spreading and compaction equipment to achieve optimum lift thicknesses and compaction
- Testing and monitoring requirements (criteria and frequency) for evaluating the effectiveness of handling, spreading and compaction equipment

**Instrumentation**

- Table listing all instrumentation and site plan showing locations of instruments
- Installation procedures, details, and schedule
- Frequency/schedule of monitoring and measurements with explanation if other than 7-day frequency
- Identification of action levels for instrumentation reading, if appropriate (e.g., design basis phreatic levels at each piezometer location)
- Routine maintenance schedule and procedures
- Responsibility for plotting and evaluating data

**Surface Drainage Controls**

- Construction sequence for spillways and decants
- Construction sequence for diversion and collection ditches
- Schedule of ditch geometries and lining materials
- Acceptable repair techniques
- Cleanout and maintenance frequencies

**Impoundment Pool Monitoring**

- Schedule of required freeboard for each embankment stage
- Schedule of decant risers to be activated for each stage with corresponding minimum required crest elevation
- Schedule for relocating slurry discharge point to develop delta above normal pool
- Pumping equipment and operating levels, if appropriate
- Stage-storage and head-discharge curves
- Survey control requirements (pool and delta levels)
- Frequency of measurements

**Routine Maintenance**

- Vegetation
- Reclamation cover
- Ditches
- Decant pipe risers and emergency and principal spillways
- Outlet areas for decant pipes
- Outlets for internal drains
- Minor erosion
- Instrumentation

**General Observations and Data Collection**

- Frequency of surficial reconnaissance
- List of specific areas requiring inspection
- Description of unusual conditions or features that should be noted and reported to the Engineer
- Reference to schedule and frequency of instruments to be measured with explanation if other than 7-day frequency
- Blank inspection forms and/or data collection forms tailored for site use

**Data Review and Reporting Requirements**

- Frequency of data review (including plots of pool, piezometers, and seepage data) by the Engineer and Operator
- Evaluation of conformance factors (embankment alignments, moisture/density test results, surface drainage channel geometries, impoundment freeboard, decant levels and serviceability) or adverse condition indicators (seepage flows, piezometer readings, erosion, slope movement, settlement and subsidence) by the Engineer and Operator
- Appropriate document for noting non-conformance factors and adverse condition indicators (weekly reports, monthly progress reports, annual reports) with recommended courses of action for such situations by the Engineer and Operator
- Summary of regulatory reporting requirements

**Emergency Management**

- Description of items that constitute a hazardous condition, including MSHA's hazardous conditions program (30 CFR § 77.216-3(e))
- Reporting requirements and contact information
- Emergency Action Plan updating requirements (for significant or high hazard potential impounding embankments)

### 11.1.5 Calculation Brief

The term "calculation brief," as used herein, refers to an organized compilation of engineering analyses and calculations associated with facility design prepared for documentation and for facilitation of regulatory review. The engineering parameters used in the analyses should be substantiated and assumptions should be supported. In addition to the design report, plans, and specifications, the calculation brief is an important part of the documentation of coal refuse disposal facility design. A calculation brief should include the following:

- Coal refuse production rates (by weight and volume) and anticipated facility life
- Starter embankment and refuse disposal staging (impoundment and embankment volumes by stage)

- Hydrology and hydraulic analyses (sedimentation control, design storm routing, decant design, spillway channel and drainage ditch designs, dam breach analysis)
- Stability analyses (including seismic hazard assessment)
- Settlement analyses
- Seepage analysis and internal drain design (including filter design)
- Surface drainage channel lining design
- Buried conduit structural and durability analysis
- Design of appurtenant structures (trashracks, thrust blocks, stilling basins, etc.)
- Subsidence analysis, pillar stability analysis, breakthrough potential evaluation, and mine barrier design
- Environmental analyses

## 11.2 PLANNING AND SCHEDULING

Planning and scheduling of operations for coal refuse disposal includes the following:

- Time required for site selection, geotechnical investigation and testing, environmental assessments, preliminary and final design, and for obtaining regulatory permits/approvals
- Stipulations associated with current or future mining, such as anticipated life of mine and mining within or near the embankment and impoundment area
- Current and predicted future rates of production of coal refuse furnished by the Operator
- Anticipated physical and chemical properties of the material to be disposed
- The rate and method of transport or hauling of material to the disposal area
- The capability of the materials handling equipment to place, spread and/or compact refuse
- The planned embankment configuration, crest elevation and impoundment capacity at any given time
- The anticipated pool level and settled fine refuse level at any given time
- Construction timing of facility appurtenances related to disposal operations
- Potential delays or special procedural requirements related to weather, work suspensions, regulatory agency stipulations or other circumstances beyond the control of site personnel.

Construction of some features, such as drainage control structures, which are constructed or extended during the facility operation, may require considerable planning and scheduling if they are to be completed by the mine operator’s forces. Otherwise, the services of a construction contractor may be needed for completion of the work in a timely manner.

The above items should be re-evaluated periodically as changes in mining operations occur. Lesser considerations, including those related to specific mine and site locations, are discussed throughout this Manual. Through proper planning and scheduling of the various development aspects of the coal refuse disposal facility, operations can proceed in an economical and efficient manner. Early identification of production changes and their impact on the disposal plan and timely preparation of design modifications will allow more flexibility in meeting long-term disposal requirements.

### 11.2.1 Planning of Coal Refuse Disposal Operations

Plans for coal refuse disposal operations differ from plans for typical construction projects because they must account for the following:

- The disposal facility will usually be in operation for many years necessitating long-term and somewhat speculative planning and timely modifications as conditions change.
- Disposal operations will occur under a variety of weather conditions. The construction of facility appurtenances must be properly timed to avoid delaying or interfering with disposal operations.
- The configuration and characteristics of a refuse embankment during facility development must suit changing conditions frequently unrelated to the final abandonment condition. For example, at impounding facilities, the impoundment storage plus the spillway outflow must be sufficient in combination to handle the design storm hydrograph at all times.
- Over the entire period of disposal operations, changes in equipment, technology and regulatory requirements may necessitate changes in schedule and operations. On-going reviewing and updating of implementation procedures are required.

Equipment requirements should be evaluated as part of the planning of coal refuse disposal operations. The equipment used for haulage, spreading and compaction should be determined based on production forecasts, and all aspects of the process should be balanced such that the specifications (lift thickness, density, moisture content, grading) for material placement can be met. When conveyors are used to provide haulage to the disposal surface, the equipment must be capable of spreading and compacting the refuse such that lift thickness, moisture content and density specifications are met.

#### 11.2.1.1 Long-Term Planning

Long-term planning for refuse disposal operations is concerned with decisions and actions that affect implementation of the overall general plans discussed in Chapter 4. Items that should be considered in the long-term planning include:

- Anticipated mine life
- Property acquisition
- Proximity to the preparation plant
- Time periods associated with obtaining permits/approvals
- Equipment selection and procurement
- Infrastructure requirements
- Refuse disposal techniques
- Timing for construction of facility appurtenances

Property acquisition often entails lengthy transactions associated with price negotiations and legal documentation. The acquisition of properties for a refuse disposal facility should be based upon the ultimate refuse disposal capacity that will be required over the life of the mine. Acquisition of all necessary property at the initiation of refuse disposal operations may not be required because the facility will not occupy the full disposal area for many years. Thus, an agreement to purchase or lease additional property at a later date may be satisfactory.

The equipment and support structures in place at the start of disposal operations should not only meet short-term needs, but should continue to be fully functional as the disposal area is developed. Selection of hauling equipment based only upon initial disposal requirements can lead to inefficient equipment use before the equipment is fully depreciated. Factors such as haul distance, haul road alignment and grade, and refuse production affect the optimization of equipment selection. Loss of equipment efficiency due to age and wear must also be considered in long-term planning.

Some types of equipment have significantly shorter useful life expectancies than others, and it may be possible to have the replacement and upgrading of site equipment coincide with major changes in the facility.

A key aspect of long-term planning of refuse handling at the point of disposal involves analysis of the spreading and compaction of coal refuse that will be required for construction of the embankment. Achievement of specified compaction requires planning for, acquiring and using suitable equipment.

Planning for construction of facility appurtenances, infrastructure, and related items is particularly important if the disposal of refuse is not to be interrupted during long-term operations. With proper long-term planning, construction can be accomplished with minimum interference with disposal operations.

#### 11.2.1.2 Short-Term Planning

Short-term planning is mainly concerned with current and near-term disposal operations and associated construction activities. Short-term planning should result in:

- Facility development in a manner that does not delay refuse disposal operations
- Completed construction conforming to design and regulatory requirements
- Maximum utilization of on-site equipment and materials
- Control of costs during the completion of all tasks

It is ultimately the facility operator's decision as to what specific planning and scheduling techniques are employed. It should be recognized that short-term planning for the development of coal refuse disposal facilities may differ from long-term planning in several respects. Some short-term construction may be accomplished by the operator using on-site labor and equipment. Therefore, manpower and equipment must be available at the site to accomplish needed construction without interference to mining, coal preparation or refuse disposal activities. Utilizing existing staff and equipment for multiple purposes is an essential part of short-term planning.

Many aspects of operational planning are governed by technical design and/or regulatory requirements. Short-term design storm criteria should be established for facility start-up and abandonment periods, as discussed in Section 9.5. A key aspect of operational planning is maintenance of the embankment configuration and spillway capacity during disposal operations, when long-term design storm criteria must be met. Spillways, decants, drains and other hydraulic appurtenances must be constructed without loss of facility function and with expansions sequenced to maintain safety and environmental control. Periodic expansions of hydraulic structure capacity should be planned such that long-term design storm criteria are met. Any temporary periods during such expansions when flood routing capacity is unavoidably reduced or limited must be minimized. Planning for such expansions should include: (1) construction procedures, (2) evaluation of the impact of the construction on design storm management and the capacity of impoundment and hydraulic structures, (3) provisions for a monitoring program, (4) a schedule for the expansion work, and (5) potential contingent actions in the event of major storms.

Under emergency conditions, it may be necessary to accomplish some tasks in the shortest possible time. Providing increased spillway capacity for an existing impoundment, stopping embankment leakage, or stabilizing a sloughing embankment are examples of such emergency conditions. Using on-site labor and equipment may not provide a satisfactory solution in such circumstances, as the needed manpower and equipment may not be available. Thus, contracting of work, rental of additional equipment, employment of contractors with special skills, or working during adverse weather


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conditions may be required, thus increasing costs. Effective short-term planning is important in these situations and can minimize unanticipated expenses.

### 11.2.2 Scheduling Methods and Application

Scheduling refers to the selection of dates for starting each identified task and the assignment of a period for completion. In other words, scheduling represents the time sequence and duration aspects of planning. The following are industry-accepted techniques that can be used for both long-term and short-term scheduling:

- Intuitive judgment/experience
- Bar chart
- Critical Path Method (CPM)
- Program Evaluation and Review Technique (PERT)

#### 11.2.2.1 Scheduling Data

With any scheduling technique, assumptions and input data greatly influence the outcome. Therefore, it is important that the assumptions and data used to generate the schedule are evaluated and agreed upon by key operational personnel. Otherwise, the results of the scheduling exercise many not be valid and may possibly be misleading. Input data used in short- and long-term scheduling associated with development, construction and operation of a refuse disposal facility may include:

- Mine development and coal preparation plant construction times
- Refuse generation rates (present and future)
- Design and permitting times
- Specialized material lead times
- Equipment delivery lead times
- Contractor lead times
- Site development and support facility construction times
- Start date of refuse generation or date when refuse facility is required to be operational
- Refuse construction milestone dates
- Regulatory requirements for facilities to be capable of handling design storm runoff, especially at start-up and decommissioning

Acquiring the above data requires a thorough understanding of the construction and operation of refuse disposal facilities, and knowledgeable personnel should be consulted in the very early stages of planning for a refuse facility. During the initial phases of planning for a new refuse facility, available data regarding the coal seam to be mined and the proposed preparation process to be employed may not be well known. As the planning process moves forward, refinement of the input data should be performed as new information becomes available.

The operator should utilize as many resources and information sources as practical when performing initial planning and scheduling for a new refuse facility. Initial data for refuse generation rates can generally be obtained from process flow diagrams for the proposed preparation plant or from nearby active preparation plants processing coal from the same coal seam. Permitting requirements and associated approval periods can normally be obtained by contacting the applicable regulatory agencies and design consultants working in the area. Data regarding site development and related construction activities can sometimes be obtained from engineers/consultants and contractors. Once the refuse facility becomes operational and refuse is being actively placed, more detailed site data will be available.

Accurately quantifying refuse generation rates for both coarse and fine refuse is important for both long-term and short-term planning. Refuse generation rates may change gradually or abruptly over the life of a refuse disposal facility. The rate of refuse generation and the ratio of coarse to fine refuse are the governing factors that dictate the construction sequencing and ultimate life of a refuse disposal facility. Accurately knowing the rate of refuse production will allow for better forecasting and budgeting of required site development and support facility construction activities. As mentioned earlier, impounding facilities must be designed such that the design storm hydrograph can be safely retained and/or passed through the spillway. Typically, the embankment crest level must be maintained at a minimum height above the level of the impoundment. Knowledge of the refuse generation rate will facilitate maintaining the required crest level.

An effective method for establishing accurate refuse generation rates is through analysis of periodically collected site topographic data. This method requires at least two sets of topographic data obtained at known dates. The time period between data collection should be sufficient to allow for the placement of a considerable volume of refuse. The two sets of topographic data can then be used to determine the net in-situ refuse volume. The rate of refuse generation is then the net volume divided by the elapsed time. This method is applicable to both slurried fine refuse and coarse refuse. In the case of slurried fine refuse, the receiving impoundment must be sounded to determine the top of settled fine refuse. The frequency for performing such analyses depends upon the mining operations and level of accuracy desired. Annual analysis is consistent with MSHA's annual reporting requirements. It is not unreasonable for refuse rates to be evaluated semi-annually, especially during early phases of facility development. Of course, any time that mining conditions or plant operations change, when the preparation plant accepts coal from different sources, or when the plant is modified, changes in refuse characteristics and production rates must be accommodated. This may entail re-evaluation of engineering properties of the refuse, including the refuse grain-size and compaction testing, in order to evaluate impacts on the strength and hydraulic conductivity of the fill and enable tracking of material placement and embankment construction.

#### 11.2.2.2 Applicability of Scheduling Techniques

Some disposal facility operations are relatively simple and consist of only a few activities or tasks. In these cases, scheduling by managers based upon their past experiences and intuitive judgments may be adequate for efficient implementation of operation plans. As site operations become more extensive and complex, more formal scheduling methods become increasingly valuable for evaluating the economic, technical and time implications of task completion. Bar chart scheduling is the least complicated formal scheduling method and is applicable to most small refuse disposal operations. Large disposal facilities often have many interrelated activities, and for these sites, use of the CPM or PERT scheduling methods may be more suitable.

As the sophistication of the scheduling process increases, management time and costs also increase. Generally, this investment has an early and valuable benefit through reduction of errors and omissions and lessening the degree of management control required during operation. However, it is possible to over-refine a schedule by subdividing the required tasks into too many activities or by projecting the schedule beyond the point where the data provide dependable information.

Often the best approach to scheduling incorporates two or more scheduling methods. For example, short-term more well-defined plans can be scheduled with considerable detail using CPM or PERT, and long-term, more broadly-defined plans can be conceptually scheduled using a bar chart. Intuitive judgment may be used for updating or modifying the more complex schedules.

It is emphasized that regardless of the approach, schedules must be periodically updated. This is especially important for long-term coal refuse disposal, where technology, regulations and equipment capabilities may change with time. Through updating of the schedule, operations can be regularly re-evaluated. Thus, the schedule becomes an effective management tool for decision making and operations planning throughout the entire operation period of the coal refuse disposal facility.

Because each mine operator has unique scheduling requirements and employs different scheduling techniques, it is not feasible to specify scheduling techniques for use at specific types of refuse disposal sites. The most important considerations are that the scheduling techniques employed meet the needs of the mining operation and that the design capacity of the disposal facility and compliance with critical parameters (e.g., freeboard, decant level, crest level) are maintained.

## 11.3 REFUSE TRANSPORT

Refuse transport systems are used for conveying coal refuse from the preparation plant to the disposal area. The purchase, operation and maintenance of these systems can represent a significant portion of the total cost of refuse disposal. The refuse transport system has impacts upon the construction and layout of the refuse disposal facility and in many cases dictates the type of handling, placement and compaction equipment required. As discussed previously, methods for placing and compacting refuse control the geotechnical characteristics and particularly the strength properties of the in-place refuse. Therefore, it is important that the refuse transport system be carefully evaluated as part of refuse disposal facility planning.

This section discusses effects that the selection of the refuse transport system may have on the geotechnical design and construction of a refuse disposal facility. Other sources should be consulted for the design and selection of refuse transport equipment.

Transport systems for coal refuse disposal operations typically consist of:

- Individual motorized hauling units (on- or off-road haul trucks or scrapers/pans) and associated access and haul roads
- Continuous mechanical arrangements such as conveyor belts
- Continuous hydraulic assemblies and/or pipelines for pumping slurried fine refuse

For both of the first two systems listed above, transport of the refuse typically represents the most significant portion of the disposal costs. However, handling of the refuse at either end of the transport system is also a consideration in the design of a refuse disposal facility. Sections 11.4 and 11.5 discuss equipment for handling, placement and compaction of refuse after it is transported to the refuse disposal site. Typically, loading at the preparation plant is accomplished by dumping from bins, and this is essentially the same for either transport system. Handling of refuse at the point of disposal can vary depending upon the system selected, refuse characteristics, and disposal requirements. Individual hauling units such as trucks can usually place refuse near the final disposal location and thus limit further handling. Conversely, continuous mechanical systems generally require additional refuse movement using hauling units and spreaders at the disposal area. Combinations of continuous mechanical equipment and individual hauling units are usually required to meet the needs of a disposal facility.

The anticipated refuse generation rates and the distance from the preparation plant to the refuse disposal site are the most important considerations in choosing a coal refuse transport system. For relatively low refuse generation rates, individual hauling units (on- or off-road haul trucks) are usually feasible and cost effective for transporting coarse coal refuse. As refuse generation rates increase, the economics begin to favor use of a continuous conveyor belt system for coarse refuse. In either case, slurried fine refuse will require a hydraulic system/pipeline for transport. At mines with low refuse generation rates, slurried fine refuse is sometimes pumped to small cells near the preparation plant or mechanically dewatered. Once the fine refuse reaches a state where it can be handled with excavating equipment, it is placed in haul trucks and transported to the refuse site for disposal either separately or combined with coarse refuse. With higher refuse generation rates, it may be cumbersome to dewater slurried fine refuse prior to disposal. For this case, slurried fine refuse is normally pumped directly from the preparation plant to the refuse disposal facility. Alternatively, the fine coal refuse may be mechanically dewatered at the preparation plant and transported with the coarse refuse. In any case, it is recommended that the final selection of a refuse transport system or combination of systems be based upon detailed information relative to refuse material characteristics and in-situ refuse compaction and strength requirements.

Although rarely pursued, crushing of coarse refuse and pumping with fine coal refuse has been tried in a few cases. This total refuse pumping system adds complexity to the staged construction of the impounding embankments (recovery of hydraulically placed materials for subsequent construction) and may affect the durability and life of the conveyance piping.

### 11.3.1 Trucks and Scrapers

Individual hauling units and the haul roads upon which they operate can be considered as an integrated transport system and should generally be addressed in the facility plans and specifications. This section discusses the types of hauling units available, the relative advantages and disadvantages of each, and their applicability to specific site conditions. Haul road characteristics must be considered as part of equipment evaluation. Additional information for such evaluations is provided in Section 11.6.1 and by MSHA (1999) in *The MSHA Haul Road Inspection Handbook*.

Typical hauling units include: rear-dump trucks (conventional type), bottom-dump tractor-trailers, side-dump tractor-trailers and rear-dump tractor-trailers. Hauling units are available for both on-highway use and for more rugged off-highway use. Off-highway scrapers may also be used as hauling units and have the added advantage of being able to self-load and spread the hauled materials. Each type of hauling unit has advantages and disadvantages that must be evaluated with respect to the specific requirements of disposal operations.

Individual hauling units are standard construction equipment. Thus, their capability and flexibility are frequently utilized in embankment construction. They provide a means to effectively deliver fill materials throughout the work area and to provide some compaction if their routing is distributed evenly across the disposal area.

### 11.3.2 Conveyor Belt Systems

Conveyor belts can be used to transport coal refuse from the preparation plant directly to the disposal area for controlled constructed fill or placement or to intermediate storage areas for subsequent transport by individual hauling units. Conveyor belts are particularly useful in mountainous regions where haul road construction is difficult or where steep grades decrease the efficiency or safety of operating individual hauling units. The evaluation of any transport system is primarily based on a comparative economic analysis of the cost for conveying refuse, but the handling requirements at both ends of the transport system must also be considered.

When conveyor belt systems are used for direct transport of refuse to the working surface of a constructed fill, handling, spreading and compaction equipment must be employed for placement and compaction of refuse. Direct placement of refuse with a conveyor belt and inadequate handling, spreading and compaction equipment (e.g., a dozer with insufficient capacity for spreading given the delivery rate of the conveyor) can result in refuse lifts that are either not horizontal, are too thick, or are otherwise not adequately compacted. Other sources should be consulted concerning the selection and design of conveyor systems.

## 11.4 HANDLING EQUIPMENT

Handling equipment is usually required at each end of a coal refuse transport system to: (1) load refuse at the preparation plant or point of intermediate storage, (2) haul refuse from a conveyor belt bin to the point of disposal, and (3) spread and compact refuse at the point of disposal. The principal function of the handling equipment is to spread and compact refuse in accordance with the design requirements of the refuse disposal facility so that a stable embankment is constructed. Specifically, handling equipment is used to place and spread refuse uniformly over the embankment's working surface in horizontal lifts with thicknesses and densities consistent with design specifications. The purpose of the compaction specifications is to ensure that the material placed in the embankment has the engineering properties (e.g., strength and hydraulic conductivity) used in the design.

The selection and use of handling equipment to distribute and spread refuse at the point of disposal has a considerable impact on the capability for meeting geotechnical design requirements. If the capability of the distribution and spreading equipment does not at least match the arrival rate of the refuse, layers will be too thick for proper compaction or will not receive an adequate number of passes, and as a result the compacted refuse will have lower strength and be more permeable. As discussed in Section 5.1 and Section 11.5, embankments may be designed with zones having different properties and requirements for different levels of refuse handling, spreading and compaction. For any embankment zone, it is desirable to place refuse in lifts so that the working surface can accommodate heavy equipment during adverse weather conditions and the potential for spontaneous ignition is addressed.

Table 11.2 summarizes the major types of handling equipment that serve various transport systems, excluding loading equipment. For a conveyor belt system, loading at the preparation plant will generally be continuous from relatively small hopper bins. If the transport system comprises individual hauling units (on- or off-highway haul trucks or scrapers), loading at the preparation plant may also be from hopper bins, but in this case, the hopper bins should be sized to accommodate surge storage, particularly if the hauling units operate intermittently. A limited capacity for intermediate stockpiled storage can be provided adjacent to the preparation plant, although this should generally be avoided. Loading of the coal refuse into the hauling units would then normally be performed by front-end loaders.

For conveyor belt systems, refuse must be moved from the downstream end of the transport system to the point of final disposal using hauling and/or spreading equipment. For most transport systems, an off-road haul truck and tractor dozer can be used for hauling and spreading the refuse at the disposal area. Compaction of the refuse can be accomplished with the hauling and spreading equipment and/or with separate compaction equipment. Routing of the hauling and spreading equipment over the refuse can achieve partial compaction if performed systematically. Bulldozers typically will need to make more passes over thinner lifts to achieve the same level of compaction as equipment specifically designed for compaction, and a bulldozer alone can only achieve suitable compaction by many passes over each lift (with overlapping tread coverage) if it is not interrupted by spreading requirements. Thus, matching equipment capacity to the refuse delivery rate, with suitable backup to accommodate downtime, is important and can impact the ability to use only spreading or hauling equipment for compaction.

### 11.4.1 Loading and Hauling Equipment

Although coal refuse is typically loaded from hopper bins directly into hauling units, loading from a stockpile may be required for transport systems composed of individual hauling units. For general construction or earth-moving operations, the capacity of the loading equipment should be closely matched to that of hauling units to minimize loader slack time and hauler spotting and loading time. To minimize hauler cycle time, the loader should be sized so that it can quickly fill a hauler, even though slack time for the loader may result.

TABLE 11.2 TRANSPORT SYSTEMS AND ASSOCIATED HANDLING EQUIPMENT AT THE POINT OF DISPOSAL

| Transport System | Handling Equipment and Use |
|---|---|
| Off-Highway and On-Highway Haulers | 1. Tractor dozer(s) to spread dumped refuse and to construct and maintain haul roads.<br>2. Compaction equipment for structural fill disposal of refuse – may be supplemented by routing of hauling units. |
| Scrapers/Pans | 1. Compaction equipment for structural fill disposal of refuse – may be supplemented by routing of hauling units.<br>2. Tractor dozer to shape embankment and assist with construction and maintenance of haul roads. |
| Conveyor Belt System | 1. Tractor dozer to distribute and spread refuse dumped from end of system and to construct and maintain access roads.<br>2. Short-haul equipment if distance from end of system to point of final disposal is large with tractor dozer to distribute and spread refuse.<br>3. Compaction equipment for structural fill disposal of refuse. |

Note: This list of equipment excludes handling equipment requirements at the preparation plant or other equipment requirements for construction of facility appurtenances other than access and haul roads.

Even though loaders may not be required for typical refuse disposal operations, especially those that utilize conveyor belts and bins for refuse transport, some loading capacity should be available at the disposal facility site. It is probable that loading equipment will periodically be needed for construction of other facility structures. Also, a loader is likely to be used for some unplanned aspect of refuse disposal. For example, a needed repair at some location on the embankment may make it desirable to quickly load and haul disposed refuse from another location. Loading equipment used for such general purposes should be selected on the basis of versatility.

Hauling units are usually employed for transporting refuse from conveyor belts and bins to the point of refuse disposal. These units are normally built for off-road use and can supplement compaction efforts, if used correctly. Individual hauling units are also recommended for facilities where conveyor belts transport refuse directly to the point of disposal. In this situation, if spreading equipment is unable to keep pace with the refuse generation rate, the hauling units can be used to transport refuse to other areas of the embankment working surface to prevent accumulation of refuse at the conveyor belt.

### 11.4.2 Spreading Equipment

As indicated in Table 11.2, tractor dozers are the commonly-used materials handling equipment serving the point of refuse disposal, regardless of the type of transport equipment used. If the proper number of units are available and they are sized and operated correctly, they can efficiently spread refuse in relatively horizontal layers of controlled thickness, and they can economically move refuse a significant distance. For a tractor dozer to be efficient and economical, an analysis should be performed to size it specifically to site conditions. Equipment manufacturers and experienced construction personnel should have input to the selection process. It may be useful to experiment by trying various sized tractor dozers and dozer blades at the refuse facility under normal operating conditions to determine the most economic and efficient tractor dozer/blade combination.

For coal refuse disposal operations, track-type tractor dozers are generally advantageous because of their greater ability to grip inclined surfaces at refuse embankments and their ability to perform excavation operations as part of the construction of other facility structures. Low-ground-pressure, track-type tractor dozers are also desirable for situations where low ground pressures are required for coarse refuse pushouts over settled fine refuse at impounding embankments using the upstream construction method. If the disposal surface is relatively flat and well maintained and upstream construction over fine refuse is not required, a rubber-tired tractor dozer will be attractive because of its greater speed and mobility. Detailed information regarding the sizing and capabilities of tractor dozers is provided in Church (1981) and is also available from equipment manufacturers.

Scrapers can be used to transport and spread refuse at disposal sites, minimizing the need for a tractor dozer. However, fine grading of slopes and other site construction activities frequently require the use of dozers.

### 11.4.3 Compaction Equipment

Compaction that increases density and strength and reduces the hydraulic conductivity of disposed coal refuse is essential for construction of stable embankments. Compaction is intended to achieve a homogeneous fill with relatively uniform properties over the depth of each layer or lift. Most designs and construction specifications for refuse embankments define compaction in terms of density and moisture content and leave equipment selection to the owner or contractor. However, the type of compaction equipment used is directly related to the efficiency and uniformity achieved and can also affect material breakdown. Particles of coal refuse are often susceptible to breakdown, such that following compaction, scarifying measures may be required for achieving lifts that are well kneaded together and have uniform properties.

Embankments for slurry impoundments and the downstream shell used to confine combined refuse or slurry cells typically are designed with a well-compacted, refuse-material zone placed in lifts with specified density and moisture criteria (sometimes referred to as the structural zone) to provide for stability and seepage control. Other zones of these embankments may be designed with less stringent lift thickness or compaction criteria provided that embankment stability is acceptable and the potential for spontaneous combustion is addressed.

Depending upon the specified compaction requirements, the compaction of coal refuse can normally be achieved by the systematic and consistent travel of transport and spreading equipment over refuse that has been placed in controlled lifts generally equal to or less than one foot in thickness. This method of compaction will almost always satisfy compaction requirements associated with control of burning even if the lifts are relatively thick (up to 2 feet as allowed under 30 CFR § 77.215). However, routing of hauling units over the working surface may be insufficient to consistently compact the refuse to meet typical criteria, and periodic test pad demonstrations and compaction testing should be employed to verify effective results if only hauling units are being used. For well-compacted embankments or embankment zones, specifically-chosen compaction equipment and/or procedures should generally be employed in order to achieve consistent and effective compaction.

Table 11.3 presents a general comparison of the compaction capabilities of various types of equipment moving over various refuse lift thicknesses. In all cases, the wheel or track of the equipment must pass over each area several times. Figure 11.1 illustrates this procedure. The number of passes and lift thicknesses required for obtaining various degrees of compaction is further discussed in Section 11.5.1. The resulting effect of compaction should be verified through field monitoring.

The basic types of compaction equipment generally employed at coal refuse disposal sites are:

- Rubber-tired, off-highway hauling unit(s) (preferably loaded)
- Sheepsfoot/segmented pad self-propelled roller (vibratory and non-vibratory)
- Smooth-drum, self-propelled or towed vibratory roller

TABLE 11.3 COMPACTION CAPABILITIES OF TRANSPORT AND SPREADING EQUIPMENT

| Equipment | Relative Lift Thickness | Effect of Compaction |
|---|---|---|
| On-Highway Hauling Units | Very Thin | Fair to Good depending on size of unit |
| | Medium | Poor |
| Off-Highway Hauling Units | Thin | Good Depending on size of unit |
| | Medium | Fair to Good depending on size of unit |
| Scrapers: | | |
| Double-Axle Mover | Thin | Fair |
| Track-Type Mover | Very Thin | Generally Poor – Good for thin lifts if material is clean and granular |
| Tractors: | | |
| Rubber-Tired Tractor | Thin | Fair |
| Track-Type Tractor | Very Thin | Generally Poor – Good for thin lifts if material is clean and granular |

Note: Proper overlap of wheel or track and multiple passes over each area is required in all cases (Figure 11.1)
The resulting effect of compaction should be field monitored and verified.

Loaded rubber-tired off-highway hauling units are effective for compacting both cohesive and granular materials due to the heavy weight of the loaded equipment concentrated at the relatively small footprint of the tires. Sheepsfoot, self-propelled rollers are generally most effective on cohesive materials with a high percentage of silt- or clay-sized particles. However, if the sheepsfoot roller has a vibratory capability, it will also be effective on granular materials such as coarse coal refuse. Smooth-drum vibratory compactors are most effective on granular materials and are useful for surface sealing to minimize infiltration.

Vibratory rollers, either smooth-drum or sheepsfoot, are better suited for coarser materials containing small amounts of clay-sized particles. According to a study performed on test pads of coarse refuse, Saxena et al. (1984) found that either a vibratory smooth-drum roller or a vibratory sheepsfoot roller were effective for compaction of lift thicknesses up to 1 foot thick. The vibratory action of these types of compactors, which can usually be adjusted, is obviously important for achieving compaction. The vibration associated with the operation of track-type tractor dozers is likely a key component that facilitates the compaction of granular materials, as indicated in Table 11.3. Manufacturers' literature, information in periodicals, and Church (1981) provide information on the compaction force associated with specific types of equipment.

Because the characteristics of coal refuse vary considerably, selection of the most appropriate compaction equipment should be based upon both material and site-specific factors, and the selected equipment should be capable of achieving specified strength and hydraulic conductivity requirements. Vibratory-type compaction equipment has been found to be effective for compacting coal refuse. Sheepsfoot rollers (vibratory or non-vibratory types) have the advantage of crushing and compacting weathered or soft rock in coarse refuse. However, larger pieces of resistant rock may make such rollers ineffective because the feet may strike the rock and lift the roller, preventing compaction of adjacent material. The same effect can occur with smooth-drum rollers. If larger, resistant rocks are prevalent at a site, loaded off-highway haul trucks should be used.


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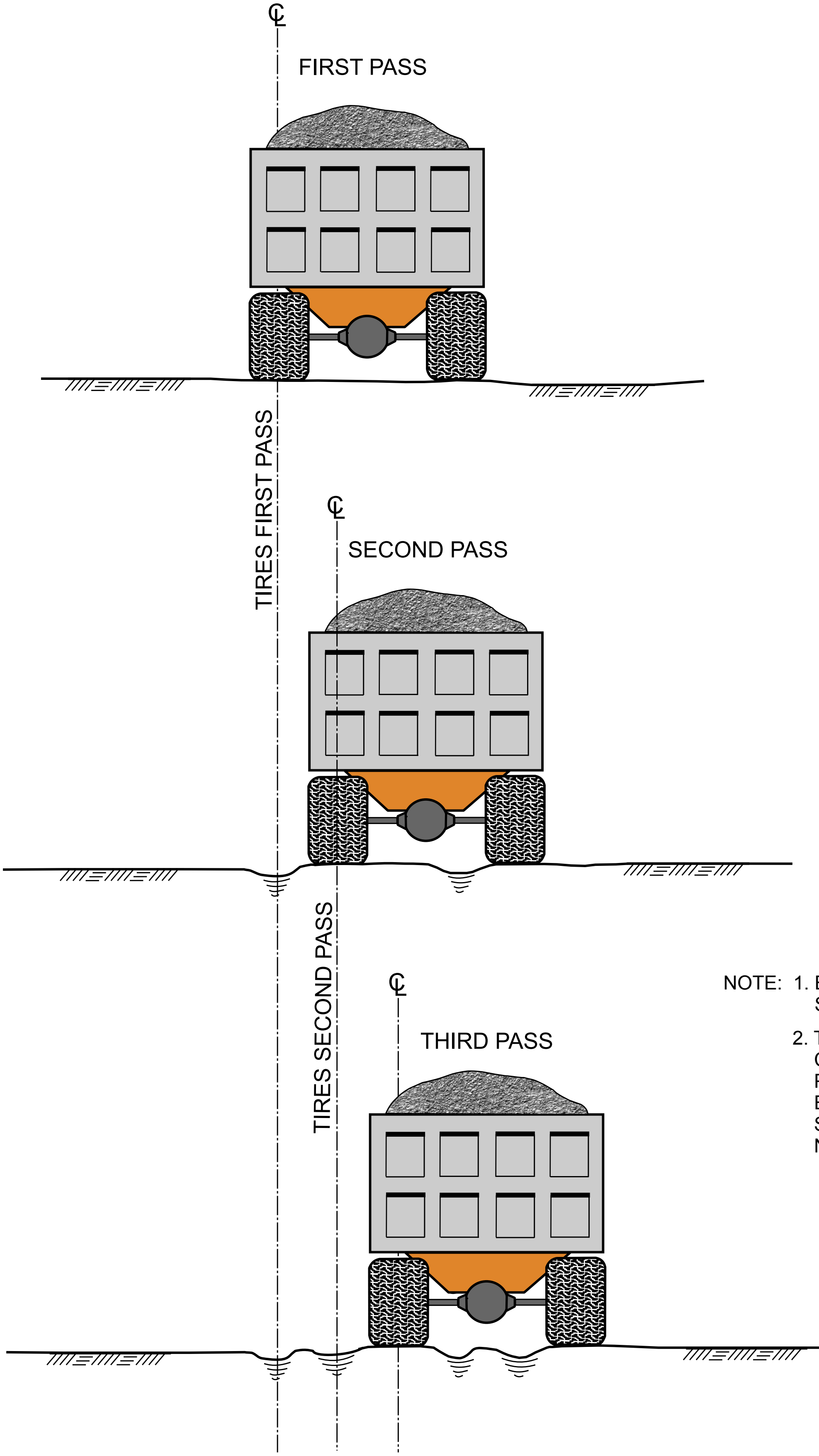



NOTE: 1. EDGES OF PASSES SHOULD OVERLAP.

2. TO ACHIEVE REQUIRED COMPACTION, MULTIPLE PASSES OF HAULING EQUIPMENT OVER THE SAME AREA MAY BE NEEDED.

FIGURE 11.1 COMPACTION BY HAULING UNITS USING SUCCESSIVE OFFSET PASSES

Both vibratory and non-vibratory compactors are generally manufactured in self-propelled, towed and pushed models. Similar to the selection of other handling equipment, compactors should be capable of handling the refuse production rate and providing adequate compaction. Evaluation of the performance of compaction equipment should be conducted for the expected refuse placement rates. The effectiveness of any compactor on coal refuse generated at a particular site will not be fully known until field performance has been evaluated through measurement of the in-situ density of the compacted refuse.

The use of spreading equipment such as tractor dozers for compaction is less effective than equipment designed for compaction because less ground pressure is exerted and generally thinner lifts are needed in order to consistently meet specified criteria. Additionally, use of spreading equipment for compaction can result in inconsistent compaction, particularly if multiple dozers are not available to accomplish spreading and compaction as separate operations. If compaction of structural fill with tractor dozers is desired, demonstration test pads should be periodically utilized in conjunction with field compaction testing to establish and document procedures for attaining consistent and acceptable results throughout the structural zone.

### 11.4.4 Use of Handling Equipment for Related Activities

The adaptability of handling equipment for performing other tasks at a mining site is an important consideration in equipment selection. However, this consideration should be secondary to the capability of the equipment for placing, spreading and compacting refuse. If the handling equipment is suitable for refuse embankment construction and can also be used to construct haul or access roads, clear disposal areas, prepare the embankment foundations, and construct spillways and drainage ditches, there will be a savings in equipment cost. Such equipment will also allow work crews that are not fully utilized on refuse disposal to work on other site construction activities.

Effective refuse disposal should be the predominant handling equipment selection consideration. However, at some facilities, the generated refuse may not be of sufficient quantity to keep handling equipment busy on a full-time basis. For these sites, multiple-use capabilities for the spreading equipment are important.

## 11.5 CONSTRUCTION AND PLACEMENT OF EMBANKMENT MATERIALS

As discussed in Chapters 5 and 6, the structural portions of a coal refuse disposal facility must be constructed in a controlled manner meeting technical design requirements. This is particularly true for the refuse embankment and its associated drainage controls. Coal refuse disposed in these portions of the facility, as previously discussed, is referred to as constructed or structural fill refuse. Fill at other portions of the facility, where less stringent compaction requirements may apply, is referred to as placed refuse.

Earthen fill or refuse that is placed as structural fill should be spread at a specified lift thickness and compacted to specified density and moisture content criteria such that material properties are consistent with facility design requirements. Placement of structural fill should be performed in generally horizontal lifts. Figure 11.2 shows several correct and incorrect methods of refuse placement. As discussed in Chapters 4 and 5, those portions of the facility that will require structural fill refuse disposal should be identified during site selection and facility planning. After placed refuse has been built up through many lifts, little can be done to densify it to structural fill specifications. Therefore, the impact on future site development of placed refuse fill with lower compaction standards must be fully understood.

### 11.5.1 Embankment Fill

Embankment fill at a coal refuse disposal facility generally consists of coarse refuse or earth and rockfill borrow materials placed in specified stages or zones. For instance, many impounding facili-

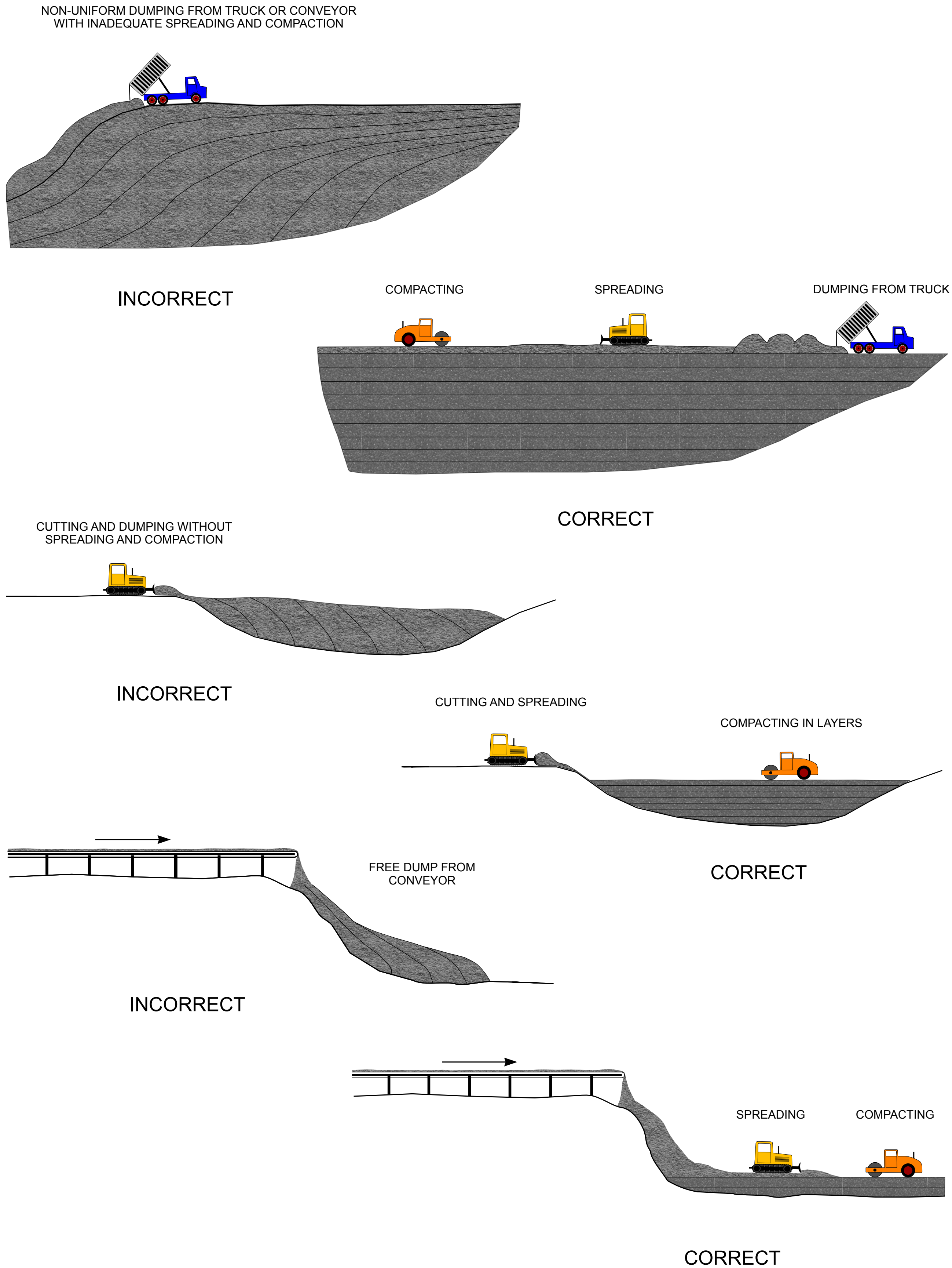



FIGURE 11.2 PROCEDURES FOR CONTROLLED PLACEMENT OF REFUSE

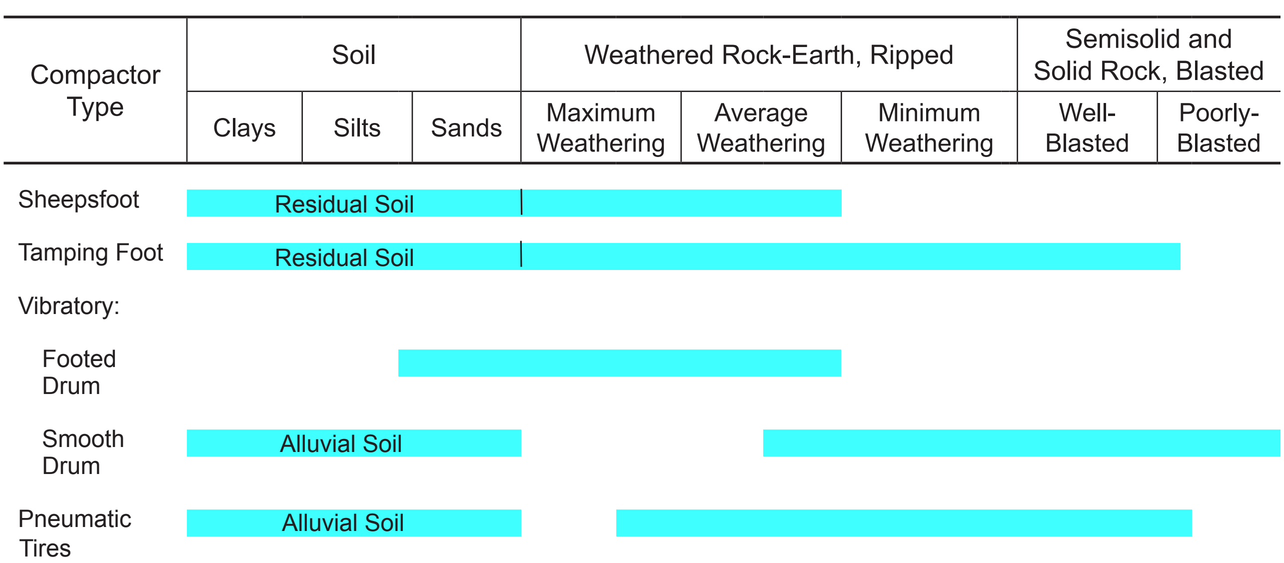
ties consist of an initial stage embankment constructed of soil and rockfill, with subsequent coarse refuse embankment stages that increase the height and capacity of the impounding facility. In many respects, placement and control at the facility embankment are not unlike that for earth and rockfill dams. However, there are major differences in timing because construction extends over the total operational period of the facility, which is usually many years. Differences also occur in materials selection because refuse embankment construction is based on maximum use of refuse and minimum use of borrow materials.

The placement and compaction effort for embankment fill refuse at an impounding facility is generally more stringent than that for a non-impounding facility. In both cases, the refuse should be placed in controlled lifts and compacted as required by the facility plans. Lifts are generally horizontal and extend over a large portion of the embankment.

Compaction of coarse refuse or soils in an impounding facility is intended to produce a well-compacted zone consisting of uniform, consistent and dense lifts. This is accomplished by limiting the lift thickness of the refuse or soil and by compacting the lifts to achieve specified strengths. Guidance for compaction of soil and rockfill materials is available from a number of sources, including Church (1981), DOD (2005), and USBR (1998). Table 11.4 presents published guidance (Church, 1981) for compaction of residual soil, weathered rock, durable rock, and alluvium. As indicated in the table, the compactive effort may be applied by a range of actions including pressure, kneading, impact and vibration. Various compactive actions can achieve compaction, but the efficiency and effectiveness for overcoming problem moisture conditions varies. Table 11.5 presents published guidance (DOD, 2005) for various types of equipment and materials with recommended base lift thickness, typical passes or coverages, and equipment characteristics. This table provides initial guidance only; actual specification of the lift thickness or selection of equipment and passes is a function of the design requirements or construction conditions.

Experience and studies (Saxena et al., 1984) have shown that typical coarse refuse spread in lift thicknesses of one foot or less can usually be compacted to densities sufficient for embankment stability at impoundments. Normally, refuse for these applications is placed in one-foot-thick lifts and compacted to at least 95 percent of the maximum dry density at minus two to plus three percent of optimum moisture as determined from the Standard Proctor test, which is described in ASTM D 698,

TABLE 11.4 COMPACTION GUIDE FOR MATERIAL TYPES

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"Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft$^3$ (600 kN-m/m$^3$))." In some cases, a more stringent compaction requirement may be necessary for impounding facilities depending upon the geotechnical characteristics of the embankment material. For instance, soils used as embankment fill will likely require a lift thickness of less than one foot to achieve the desired density.

The oversize correction provision of ASTM D 698 for material retained on the ¾-inch sieve should be followed, including the density and moisture content correction as per ASTM D 4718. If the correction is applicable, but is not applied, then the measured field density could overestimate the true compaction being achieved. As a result, while it might appear that the compaction specifications are being met, the actual degree of compaction could be less than specified, leading to problems with stability and seepage. In situations where there is a large percentage of oversize durable rock, such as sandstone, there can be a significant difference in the specific gravity, and laboratory measurements should be made of both the oversize and remaining material specific gravity (rather than adopting assumed values) when applying the correction. Application of ASTM D 698 may be difficult or may even be precluded when coarse refuse contains more than 25 to 30 percent of plus-¾-inch particles, based on application of the oversize correction provisions of the procedure. Sometimes the oversize correction yields unreasonable target densities (i.e., higher than achievable). In such cases other compaction test methods or field procedures should be considered. While use of the relative density test in accordance with ASTM D 4253, "Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table," and ASTM D 4254, "Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table," may be a possibility, this is generally not recommended because of the fine content in coal refuse.

Alternative material testing methods may be employed when more than 25 or 30 percent of plus-¾-inch particles are encountered. One such testing method is specified in Appendix VIA of the USACE Publication EM 1110-2-1906 titled "Laboratory Soils Testing" (USACE, 1986). This method employs a 12-inch-diameter mold that accommodates larger particle sizes. Disadvantages to this method are that it is more time consuming and costly than the ASTM D698 method, and many geotechnical laboratories are not equipped to perform the test. However, if refuse with a significant proportion of oversize particles is routinely generated, it may be desirable to use the USACE test to supplement or replace other methods.

Another possible method for compaction control is using a method specification such as the roller pass test, as described in WVDOT (1999) Standard MP-700.00.24. This procedure consists of preparing a roller pass test strip with fresh coarse refuse at the optimum moisture content. Compaction of fresh refuse is performed with the equipment that will be used during embankment construction (e.g., vibratory smooth-drum roller or similar or with loaded haul equipment), using sufficient passes (usually not more than 12) to compact the material without rutting or noticeable working surface deflection. Initial density tests are then performed. Additional compaction using two passes of the equipment is performed, and additional density testing is conducted to confirm that the maximum density has been achieved (i.e., the incremental difference in the average wet densities is less than one pound per cubic foot). In this case, the target maximum density and moisture content for compaction would be based on the roller pass maximum dry density.

To achieve the desired compaction and the desired geotechnical characteristics for a structural zone or embankment, the water content of the refuse must be controlled. This can be difficult during winter and inclement weather periods when there may not be sufficient space or time for drying or thawing wet or frozen materials. Embankment zones that may be designated for such conditions are discussed in Section 11.5.3.

Typically, refuse piles and other non-impounding facilities can be designed with embankment zones placed in greater than one-foot lift thicknesses and/or can be compacted to a density lower than 95

## TABLE 11.5 SUGGESTED COMPACTION EQUIPMENT AND METHODS

| Equipment Type | Applicability | Typical Requirements for Compaction of 95 to 100 Percent of Standard Proctor Maximum Density | | | | | Possible Variations in Equipment |
|---|---|---|---|---|---|---|---|
| | | Compacted Lift Thickness (in) | Passes or Coverages | Dimensions and Weight of Equipment | | | |
| | | | | Soil Type | Foot Contact Area ($ft^2$) | Foot Contact Pressures (psi) | |
| Sheepsfoot Rollers | For fine-grained soils or dirty coarse-grained soils with more than 20 percent passing No. 200 sieve. Not suitable for clean, coarse-grained soils. Particularly appropriate for compaction of impervious zone for earth dam or linings where bonding of lifts is important. | 6 | 4 to 6 passes for fine-grained soil | Fine-grained soil (PI > 30) | 5 to 12 | 250 to 500 | For earth dam and related embankment work, articulated self- propelled rollers are commonly used. For smaller projects, towed 40- to 60-inch drums are used. Foot contact pressure should be regulated so as to avoid shearing the soil on the third or fourth pass. |
| | | | | Fine-grained soil (PI < 30) | 7 to 14 | 200 to 400 | |
| | | | 6 to 8 passes for coarse-grained soil | Coarse-grained soil | 10 to 14 | 150 to 250 | |
| | | | | Efficient compaction of soils wet of optimum requires less contact pressure than the same soils at lower moisture contents. | | | |
| Rubber Tire Roller | For clean, coarse-grained soils with 4 to 8 percent passing the No. 200 sieve. | 10 | 3 to 5 coverages | Tire inflation pressures of 35 to 130 psi for clean granular material for base course and subgrade compaction. Wheel load 18,000 to 25,000 lbs. | | | Wide variety of rubber tire compaction equipment is available. For cohesive soils, light wheel loads, such as provided by wobble-wheel equipment, may be substituted for heavy wheel load if lift thickness is decreased. For granular soils, large-size tires are desirable to prevent shear and rutting. |
| | For fine-grained soils or well graded, dirty, coarse-grained soils with more than 8 percent passing the No. 200 sieve. | 6 to 8 | 4 to 6 coverages | Tire inflation pressure in excess of 65 psi for fine-grained soils of high plasticity. For uniform clean sands or silty fine sands, use large-size tires with pressures of 40 to 50 psi. | | | |
| Smooth Wheel Rollers | Appropriate for subgrade or base course compaction of well-graded sand-gravel mixtures. | 8 to 12 | 4 coverages | Tandem-type rollers for base course or subgrade compaction; 10- to 15-ton weight; 300 to 500 lb per lineal inch of rear roller width. | | | 3-wheel rollers are obtainable in a wide range of sizes; 2-wheel tandem rollers are available in the range of 1 to 20 tons. |



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TABLE 11.5 SUGGESTED COMPACTION EQUIPMENT AND METHODS
(Continued)

| Equipment Type | Applicability | Typical Requirements for Compaction of 95 to 100 Percent of Standard Proctor Maximum Density | | | Possible Variations in Equipment |
|---|---|---|---|---|---|
| | | Compacted Lift Thickness (in) | Passes or Coverages | Dimensions and Weight of Equipment | |
| Smooth Wheel Rollers | May be used for fine-grained soils other than in earth dams. Not suitable for clean, well-graded sands or silty, uniform sands. | 6 to 8 | 6 coverages | 3-wheel roller for compaction of fine-grained soil; weights from 5 to 6 tons for materials of low plasticity to 10 tons for materials of high plasticity. | 3-axle tandem rollers are generally used in the range of 10 to 20 tons weight. Very heavy rollers are used for proof rolling of subgrade or base course. |
| Vibrating Sheepsfoot Rollers | For coarse-grained soils: sand-gravel mixtures | 8 to 12 | 3 to 5 | 1 to 20 tons ballasted weight. Dynamic force up to 20 tons. | May have either fixed or variable cyclic frequency. |
| Vibrating Smooth Drum Rollers | For coarse-grained soils: sand-gravel mixtures – rock fills | 6 to 12 (soil) to 36 (rock) | 3 to 5<br>4 to 6 | | |
| Vibrating Baseplate Compactors | For coarse-grained soils with less than about 12 percent passing No. 200 sieve. Best suited for materials with 4 to 8 percent passing No. 200 sieve, placed thoroughly wet. | 8 to 10 | 3 coverages | Single pads or plates should weigh no less than 200 lb. May be used in tandem where working space is available. For clean coarse-grained soil, vibration frequency should be no less than 1,600 cycles per minute. | Vibrating pads or plates are available, hand-propelled, single or in gangs with width of coverage from 1-½ to 15 ft. Various types of vibrating-drum equipment should be considered for compaction in large areas. |
| Crawler Tractor | Best suited for coarse-grained soils with less than 4 to 8 percent passing No. 200 sieve, placed thoroughly wet. | 6 to 10 | 3 to 4 coverages | Vehicle with "standard" tracks having contact pressure not less than 10 psi. | Tractor weight up to 85 tons. |
| Power Tamper or Rammer | For difficult access and trench backfill. Suitable for all inorganic soils. | 4 to 6 for silt or clay; 6 for coarse-grained soils | 2 coverages | Minimum weight 30 lb. Considerable range is tolerable, depending on materials and conditions. | Weights up to 250 lbs, foot diameter 4 to 10 in. |

(ADAPTED FROM DOD, 2005)

percent of the maximum dry density. For a refuse pile, MSHA regulations do not permit lift thicknesses in excess of 2 feet unless an adequate factor of safety has been demonstrated. However, lift thicknesses of two feet (or greater) may preclude uniform compaction. From a technical standpoint, coarse refuse at non-impounding facilities that contains predominantly large particles similar to rock fill can be placed and compacted in larger lifts, if adequately-sized compaction equipment is used. Since coarse coal refuse typically consists of both rock and soil particles, one to two-foot lifts can typically be used if suitable compaction equipment is employed.

Appropriately-sized equipment does not guarantee that placement and compaction of refuse will be as desired. The coordination of equipment operations and sequencing of refuse placement greatly affects the level and quality of compaction achieved. Refuse should be placed in piles on the working surface and spaced so as to allow spreading equipment to achieve the specified lift thickness with minimal effort prior to compaction. Refuse should be spread away from a conveyor discharge point to the specified lift thickness. A sequence or progression of refuse placement should be established. When handling equipment of sufficient number and size is employed using an efficient operating system, refuse should be evenly distributed on the working surface and can be spread in relatively thin horizontal lifts, allowing compaction equipment to perform under favorable conditions.

To achieve consistent and uniform compaction, successive lifts should be knitted together by scarifying smooth compacted surfaces prior to placement of subsequent lifts. This is particularly important where concentrated haul traffic has resulted in additional breakdown of the material or where smooth-drum rollers are used. Generally, little scarifying is necessary where padded or sheepsfoot rollers are employed unless the working surface has been dormant for a long period of time or where concentrated haul traffic has occurred. A rock ripping attachment for a tractor dozer may be required to scarify the working surface properly.

Where an intermediate crest elevation has existed for a period of time, the surface may become highly compacted from the combination of traffic and breakdown of the surface material due to weathering. Additionally, freezing conditions can result in frost heave and formation of ice lenses. If this condition is not addressed when the next lift is placed, then a layer of differing hydraulic conductivity may cause seepage to run horizontally and exit at the face of the downstream slope. Such a condition, which will lead to concerns about seepage and stability, can be addressed by scarifying or removing the top surface material prior to placing the next lift.

Special care must be taken to achieve adequate compaction at the sloped edges of each lift where, due to the lack of natural confinement, the refuse tends to move away from the equipment without densification. Although the total stability of an embankment is not significantly affected by refuse density at the slope face, loose material is susceptible to erosion and creep. To achieve adequate surface density, compaction should extend several feet down the slope. If this is not possible, the loose material should be shaved off with a dozer or excavator and pushed back onto the working surface for compaction.

When structural fill is placed against a hillside or against an existing embankment, the existing material should be keyed or benched. This can be accomplished by using a dozer to cut a sufficient distance into the slope (e.g., approximately three or four feet horizontally where the terrain is steep) as the new refuse embankment is advanced in height. Figure 11.3 illustrates the process of benching to tie structural fill into a natural slope. This process removes surface material that may not be at the required density, permits compaction at the construction interface, and reduces the tendency for a natural slip surface to develop at this critical location.

Compaction tests, as discussed in Section 11.8, should be performed relatively often during initial structural fill refuse construction when material characteristics and equipment efficiency are being

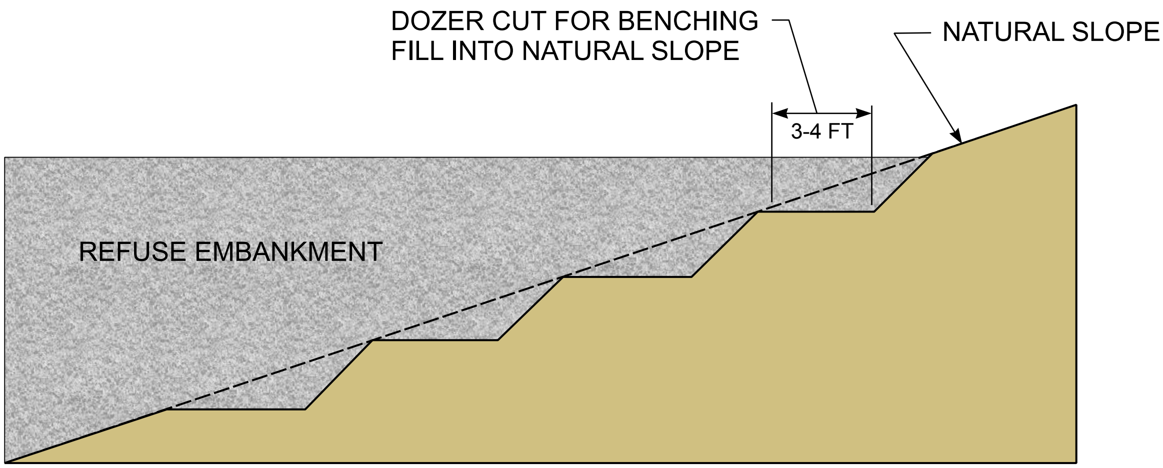



FIGURE 11.3 BENCHING OF EMBANKMENT FILL INTO NATURAL SLOPE

evaluated. Thereafter, the testing frequency can be reduced, provided that a history of successful equipment performance and density testing indicates that the desired compaction is being accomplished. A typical criterion for the frequency of compaction testing for embankment fill is: at least one density test per 2,000 cubic yards of material placed or one test for every lift placed, whichever is greater (USBR, 1998). Tests should also be performed when it is suspected that adequate compaction is not being achieved.

### 11.5.2 Upstream Construction Implementation Procedure

Incidents have occurred while establishing pushouts where bulldozers have sunk into the underlying fines and not been recovered. Even in situations where the fine refuse surface is dry, dessicated and vegetated, the underlying materials may remain soft and can exhibit sudden shear failure under equipment operation.

As indicated previously, upstream construction of an impounding embankment poses technical and construction challenges. Since upstream construction involves the development of an embankment over saturated, unconsolidated fine coal refuse, the stability of the embankment under both static and dynamic loading must be carefully evaluated. The potential for sudden failure of the pushout surface and the underlying fine refuse during upstream construction requires that special techniques and equipment be used and that the work be performed by experienced and properly trained equipment operators.

Placement of material on top of saturated, hydraulically-placed fine coal refuse results in the compression of fine materials. Since the material is initially loose and saturated, as the particles move to a closer packing, the water in the pores is placed under pressure. This excess pore-water pressure reduces the effective stress and can make the material unstable. Fill material must be placed on top of the fines at a slow enough rate that the pore-water pressure can dissipate without causing significant instability. If too thick a layer is placed too quickly, instability will occur that can adversely affect both the immediate safety of the equipment operators and the overall safety of the embankment.

It is important that equipment operators understand the potential for instability during upstream construction and the general concept that the rate of material placement during upstream construction must be controlled. Placing material thicker and/or faster on hydraulically-placed fines can be detrimental. When excess pore-water pressures are created in one area, construction activity should be moved to another area to allow pore-water pressures to dissipate.

Task-specific training should be provided to the equipment operators that will be performing upstream pushout embankment construction and to workers who will be in the vicinity of the upstream construction. The training should familiarize operators and workers with the risks associated with upstream construction and should include specific instructions for developing access to pushout areas, along with specific construction methods for performing upstream construction. Information describing the risks associated with upstream construction and features that are indicative of unstable working surfaces should be provided as part of the training program. Records documenting the training should be kept.

Certain precautions are essential for minimizing the potential for failure of coarse coal refuse placed over fine refuse. These precautions will also help to minimize the potential for occurrence of accidents associated with the upstream construction activities. These precautions include the following:

- Impoundment construction and discharge of fine refuse should be managed such that a sufficient fine refuse delta on which to initiate upstream construction is created. The delta should be as uniform as is practical, which can be facilitated by routinely moving the slurry discharge point along the upstream slope of the embankment.
- The normal pool elevation should be lowered via pumping or other means (if practical) to the lowest practical level and away from the fines delta.
- A buffer should be established from the edge of proposed pushout where high-ground-pressure vehicles such as haul trucks are excluded from travel. The width of the buffer should be established based on site-specific conditions and equipment (e.g., 50 feet has been satisfactorily used).
- Only low-ground-pressure equipment should be used to perform upstream construction within the buffer area.
- Two-way radio communication for equipment operators and mine personnel should be provided during upstream construction activities, and it is recommended that equipment operations during the initial pushout be within sight of mine personnel and that operators be provided with floatation devices (e.g., life jackets).
- Work should only be performed during daylight hours until a stable working surface is established.
- The placement of coarse refuse for upstream construction should initiate with advancement of a thick layer (typically 4 to 6 feet thick) of coarse coal refuse onto the exposed fine refuse delta. Placement of the initial lift of coarse refuse should begin along the embankment upstream slope and gradually advance upstream over the fine refuse. A portion of the advancing lift may sink into the fine refuse in soft areas or areas where the surface is saturated. It may be possible to minimize this effect by reducing the lift thickness or lowering the impoundment water level.
- Equipment working near the upstream edge of the pushout should be oriented perpendicular to the face of the active edge (i.e., no equipment should travel near and parallel to the upstream edge of the pushout).
- Pushout construction should be sequenced so that haul trucks do not travel adjacent to pushout areas until a stable working surface is established.
- Pushouts should be constructed utilizing a buffer consisting of at least one pile of coarse refuse. The buffer pile of coarse refuse should remain between the dozer and impoundment as the refuse is pushed onto the fine refuse delta. Use of this method will always keep the dozer in a safer position away from the edge of the fine refuse.
- Pushouts should be performed perpendicular to the upstream face of the embankment and/or impoundment and should be limited to a prescribed length onto the delta (e.g., 25 feet measured from the upstream edge of the embankment or stable working surface). It is recommended that the initial lift for upstream construction be

spread to a width of at least two times the push out length (e.g., 2 times 25 feet or 50 feet) before further advance of the lift upstream over the delta.
- The surface of the upstream pushout embankment should be graded to drain toward the impoundment.

Monitoring and inspection of the upstream construction area should be performed by a qualified person who is familiar with upstream construction methods and risks. Prior to and during initial pushout construction, this person should inspect the refuse embankment and the area of the upstream construction. The inspection should focus on identifying conditions that could affect the safety of the equipment operators as well as conditions that could affect the safety of the embankment. These include the following conditions:

- Development of cracks with vertical displacement or scarps in the vicinity of the pushout (the orientation and shape of the cracks may indicate shearing rather than differential settlement)
- Excessive pumping of the pushout surface
- Excessive bulging of the fine refuse delta (e.g., bulge or displacement height in excess of the pushout lift level) where work is being performed
- A situation posing a threat that the embankment could be overtopped by water or slurry
- Sudden or major subsidence of the embankment crest
- Longitudinal or transverse cracking of the embankment crest
- Major sliding/failure of upstream or downstream embankment slopes or abutment slopes adjacent to the embankments
- Unusual seepage from areas of the downstream face or from the toe of the embankment
- Unusual conditions on the embankment downstream slopes that develop during upstream construction
- Significant landslides within the impoundment area

In addition to the above conditions, embankment piezometers should be monitored before and during the upstream construction. Where development of significant pore pressures are or remain a concern for the initial pushout, new piezometers can be installed within the fine refuse to aid in monitoring of the upstream construction process. The location for piezometers should reflect the potential interference from construction activities and the likely displacements associated with upstream construction.

If any of the above listed conditions are observed, or if piezometers indicate unacceptable levels of pore pressure, the information should be reported to the Engineer and Operator, and equipment and personnel should be moved to another work area until the cause of the problem is identified and corrected. The results of the inspection should be documented.

### 11.5.3 Excess Coarse Refuse/Inclement Weather Disposal

Some coal preparation plants may generate more coarse refuse than required for impounding embankment construction (excess coarse refuse), with the result that specific embankment zones or separate embankments are designed with different material placement and compaction criteria (e.g., thicker lifts). This situation may also result in the designation of a location for inclement weather disposal, when compaction to the normal embankment specifications is precluded due to moisture or freezing conditions.

To mitigate concerns for combustion, excess coarse refuse should generally be spread in layers or lifts less than 2 feet thick. Additionally, lift placement should result in a working surface capable of supporting equipment traffic associated with subsequent disposal operations. Other geotechnical factors that must be considered before constructing embankment zones with thick lifts include settlement and hydraulic conductivity.

Placement of refuse in thick lifts may also be acceptable at non-impounding embankments and in surface mine backstack areas where such materials do not influence the stability and drainage control of the site. Note that 30 CFR § 77.215 addresses construction requirements for refuse piles. Section 77.215(h) requires that refuse piles be constructed in compacted layers not exceeding 2 feet in thickness except that the MSHA District Manager may approve construction of a refuse pile in compacted layers exceeding 2 feet in thickness where engineering data substantiate that a minimum static safety factor of 1.5 will be attained.

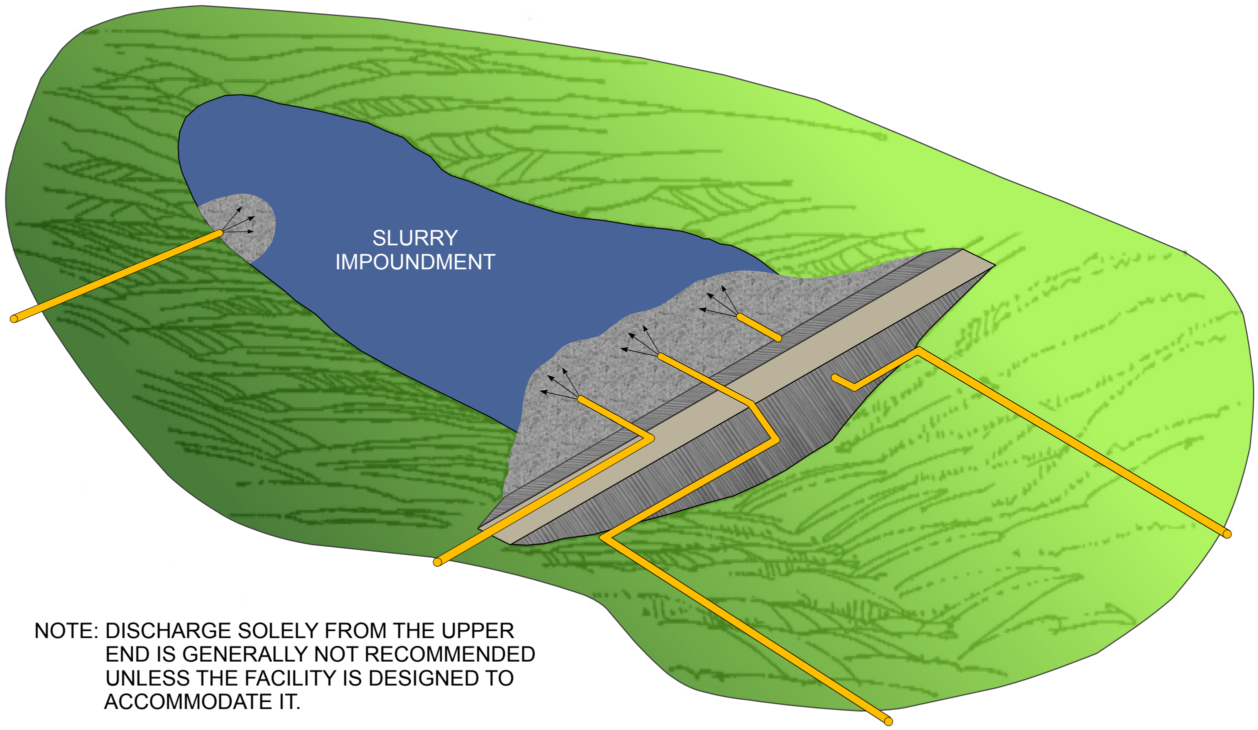
Sealing of any disposal surface that will be exposed for a long period of time is always important. Sealing requires use of smooth-wheeled vehicles (hauling units or smooth-drummed compaction equipment) rather than tamping-foot rollers, with appropriate grades provided for drainage. For final surfaces, preparation for abandonment and revegetation should follow procedures discussed in Chapter 10.

### 11.5.4 Disposal of Fine Refuse Slurry

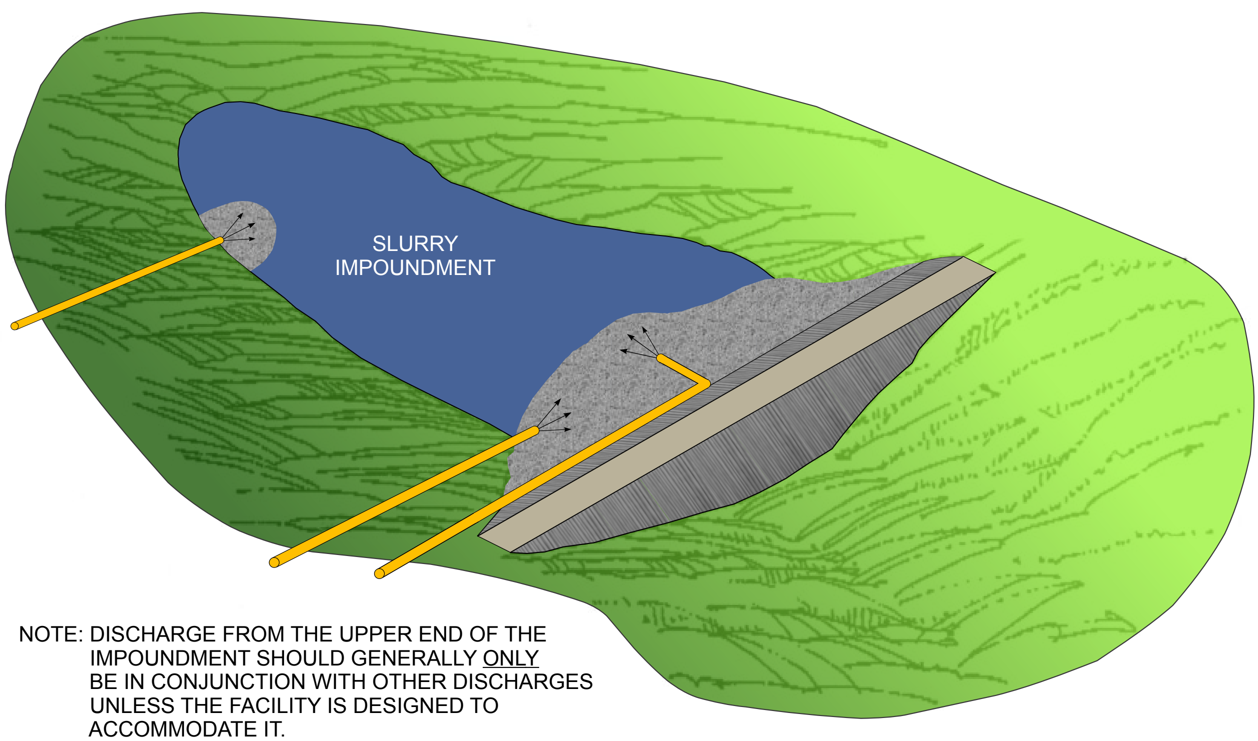
The fine coal refuse slurry disposal system is a distinct part of a coal refuse disposal facility. Slurry pipe size, composition, anchor/bracing details, discharge point locations and construction methods should be included in facility plans and specifications for implementation as part of overall refuse disposal operations. Disposal of fine coal refuse slurry is discussed here with respect to site-related planning, scheduling and the relationship to other construction and disposal operations. If possible, the disposal of fine refuse slurry should result in a fine coal refuse delta above the impoundment pool to: (1) provide the best possible foundation for upstream advancement of the embankment whether or not the facility is initially planned to be developed by the upstream construction method, (2) protect the embankment face from wave erosion by minimizing the impounded water depth at the upstream embankment slope, and (3) reduce seepage into the embankment and keep the phreatic surface associated with embankment seepage as low as possible (assuming the fine coal refuse hydraulic conductivity is lower than the embankment hydraulic conductivity). At some facilities clarified water from the impoundment is pumped to a separate cell, typically at the upstream end of the reservoir, further isolating the pool from the embankment face.

As illustrated in Figure 11.4, slurry disposal functions most effectively if the discharge point of the transport pipe is located at a relatively low elevation on the impoundment side (upstream slope) of the embankment and is periodically moved to adjacent locations along the upstream slope. The coarsest material in the slurry will be deposited in the immediate vicinity of the discharge point, leading to maximum material strength near the embankment and maximum water depth near the upstream end of the impoundment. Periodic movement of the discharge point back and forth along the upstream edge of the embankment will create a more uniform delta deposit. The slurry may be discharged at other locations to achieve slurry deposition at specific features such as mine barriers or to more fully utilize available impoundment capacity. The refuse disposal plan should discuss the type and size of equipment required to move the slurry discharge pipe around the impoundment.

Pipes transporting the slurry to the impoundment should not be placed through the embankment unless seepage and structural provisions are provided. Pipes through embankments tend to be natural paths for seepage and could result in embankment failure from internal erosion. Also, pipes installed within the embankment or along the downstream face of the embankment could cause erosion and are an environmental hazard if they leak or fail (Figure 11.4a).




11.4a INCORRECT SLURRY PIPE INSTALLATION




11.4b CORRECT SLURRY PIPE INSTALLATION

FIGURE 11.4 SLURRY DISPOSAL

### 11.5.5 Disposal of Combined Refuse

As discussed in Chapter 2, fine coal refuse slurry can be processed by dewatering with a vacuum filter, belt filter press or centrifuge. A filter cake of fines that in some instances is at a water content too high for easy transport and disposal as a solid waste material can result, particularly during inclement weather periods. Under such adverse conditions, the filter cake may be difficult to confine in haulage units. To minimize spillage and resulting degradation of haul roads, conventional trucks fitted with sealing tailgates may be necessary. As a separate waste material, filter cake typically can't be spread in lifts and compacted and will not support construction equipment.

To resolve this materials transport and disposal problem, the filter cake can be mixed with coarse refuse at the preparation plant, resulting in a combined refuse that normally can be transported in conventional trucks or by conveyor. However, watertightness of transport unit bodies is desirable, because the material is typically very wet.

Combined refuse disposal facilities are typically designed as non-impounding embankments or refuse piles. In some instances where the combined refuse is very wet, the material may not be suitable for normal embankment construction. A large area may be needed for spreading and drying the material. During wet or winter periods, movement of spreading or compacting equipment over this area may be difficult or impossible. This can lead to operational inefficiencies and larger disposal areas than normally required. If confined disposal is necessary, a structural zone or embankment may be needed for retaining the combined refuse. Such embankments must be constructed from borrowed soil and rock materials, or some of the coarse refuse must be diverted for this purpose.

The mine operator or designer should carefully evaluate the effects of combined refuse disposal prior to implementation of this type of total disposal system so that all relevant requirements and limitations are factored into the planning. The procedure for disposing of coarse refuse and dewatered fine refuse filter cake must be planned and designed specifically for conditions found at the disposal site.

### 11.5.6 Use of Amendments

Coal refuse may require amendments for neutralization and stabilization. The relative quantities and methods for combining refuse and materials such as lime, combustion ash, and kiln dust should be detailed in the facility plans, specifications and the operation and maintenance plan. Rich and Hutchinson (1990) discuss the operational implications of using lime kiln dust to neutralize and stabilize combined refuse at a West Virginia mine site using the following practices: (1) mixing the kiln dust with filter cake at the preparation plant to absorb moisture, (2) refuse cell development with elevated roadways constructed with rock for equipment access for dumping of the combined refuse, and (3) methods to shed excess water by separating the dumped piles to allow drainage prior to grading, and (4) maintaining drainage control within the refuse cell. For the cited case, an application of 2 percent by weight of kiln dust provided sufficient improvement in the combined refuse to enable effective disposal. Section 10.3.2.3 provides additional discussion of amendments.

## 11.6 RELATED ACTIVITIES

Many activities besides refuse disposal are involved in the development of a disposal facility. Activities associated with coal refuse disposal include:

- Construction and maintenance of haul or access roads
- Construction of liner systems prior to refuse placement
- Development of underdrain and spring collection systems

- Foundation preparation prior to disposal of coal refuse
- Placement of earth borrow material as structural fill and impervious cores and/or seepage control blankets
- Control of water while constructing facility appurtenances and developing the embankment foundation
- Construction of internal drainage systems within the embankment
- Excavation for spillways, ditches, drainage installations, repair work, etc.
- Construction of embankments for mine seals and barriers (e.g., fills for protecting impoundments from the influence of potential underground mine subsidence)

In general, construction procedures for these related activities are the same in mining as for heavy construction. Therefore, discussion of these topics herein is limited and is related specifically to coal refuse disposal operations.

The activities listed above and the construction of appurtenant structures subsequently discussed in Section 11.7 are similar in the sense that neither pertain directly to the primary facility purpose of refuse disposal, yet both are needed for refuse disposal to proceed. The distinction made herein is: (1) the above activities will generally be performed with the same equipment used for refuse disposal, and the materials required are basically available at the site, and (2) the structures discussed in Section 11.7 generally require special equipment and procedures, and the materials involved must be purchased.

### 11.6.1 Haul and Access Road Construction and Maintenance

Haul and access roads are an integral part of a site refuse transport system and have been a source of safety concerns. Surfacing, width, signage, runaway vehicle provisions, drainage control and berms are important design issues. Roadway layout, design and maintenance impacts the operations of the refuse disposal facility. Haul and access road locations must be determined in the initial stages of planning and design of the refuse disposal facility. Consideration must also be given to temporary haul roads required during various stages of facility construction for safe access to the working surface of the embankment. Because of the importance of disposal facility haul roads, MSHA (1999) published *The Haul Road Inspection Handbook*, which focuses on the safety aspects of haul road design. Guidance for the layout and design of haul and access roads is also provided in the U.S. Bureau of Mines publication, *Design of Surface Mine Haulage Roads – A Manual* (Kaufman and Ault, 1977), and other references.

### 11.6.2 Liner Systems

State regulations require protection of the groundwater. This may in some states necessitate the installation of a liner system to reduce the potential for impacts to the environment. The extent and type of liner system required for groundwater protection generally depends upon the environmental setting of the refuse disposal site and the potential acidity of the refuse. Liner systems are normally constructed of clay soils from on-site borrow areas or from geosynthetic materials. Geosynthetic liners may consist of a geomembrane or a clay-impregnated geotextile (geosynthetic clay liner or GCL). Clay soil liners are used when the acid potential of the refuse is low to moderate, and geosynthetic clay liners may be considered for higher acid potential refuse or when clay is unavailable at the site. Liner systems are normally installed after foundation preparations have taken place and prior to the placement of refuse. Extensive underdrain and spring collection systems are sometimes installed beneath liner systems to prevent sloughing and/or slides that could compromise liner integrity. Because of the potential for a liner to introduce a slip plane, the effect of a liner system must be evaluated in the stability analyses. Section 10.4 provides additional discussion of liner systems.

### 11.6.3 Embankment Foundation Preparation

As discussed in Section 6.3, the foundation of a coal refuse embankment will affect embankment stability, settlement and seepage. To achieve stability or to minimize potential settlement, removal of soft cohesive materials may be desirable. However, for seepage and leachate control, these materials can provide an effective seal if left in place. Thus, cost-effective foundation design for a disposal facility embankment requires that important decisions be made relative to removal or use of on-site materials.

#### 11.6.3.1 Clearing and Topsoil Stockpiling

Cutting and removal of trees, brush and other vegetation within the footprint of the embankment should be specified. Vegetative matter, if not removed, can decay and cause settlement and the formation of slip planes. Vegetative matter may also contribute to spontaneous combustion and burning. Additionally, floating trees and branches can plug hydraulic structures, particularly culverts and decants. Cleared material should be removed from the construction area or burned.

Topsoil present in areas where refuse will be placed should be removed and stockpiled for reclamation. Stockpiling should be performed in a controlled fashion in areas away from natural drainage courses and areas of planned future development. State mining regulations typically provide guidance for topsoil removal and stockpile requirements.

Within impoundment areas, trees and heavy brush should be cleared and removed so that floating debris that could impact operation of spillways and decants is not present. Soil and topsoil should be stockpiled for future use, as required. Clearing and removal of soils within the impoundment area should be sequenced so as to minimize excessive disturbance to hillsides that could cause erosion and lead to potential slope instabilities. Typically, clearing should be limited to areas that will potentially be affected by the impoundment within one or two years.

#### 11.6.3.2 Soft Soil Foundations

An effort should be made during the geotechnical subsurface exploration program to identify soft soil foundation areas. If soft soils are present where a refuse embankment is planned, removal of the soft materials may be necessary. Such removal can generally be accomplished with normal excavating and hauling equipment. Temporary access roads for construction equipment should be constructed as needed to facilitate safe operations. Depressions associated with removal of soft soils can be backfilled with either on-site borrow material or coarse refuse, as available. Some types of soft soils may be suitable for clay liner construction or for use as final reclamation cover, in which case they should be stockpiled on the site and reused.

#### 11.6.3.3 Competent Soil Foundations

If generally competent foundation materials are present in the area where embankment construction is planned, it may be possible to utilize these in-situ materials. Some over-excavation and recompaction of the material may be required if the soil type is acceptable but the in-situ density is too low. Prior to such work, the area should be cleared of vegetation and organic topsoil. Clearing and excavation/recompaction should not be performed very far in advance of refuse disposal since prolonged exposure of the foundation soil could lead to weathering and deterioration of important physical properties and/or cause environmental damage. Construction of temporary access roads and stockpiling of topsoil or other recoverable material should be performed in the manner previously described.

#### 11.6.3.4 Rock Foundations

From the standpoint of strength, rock is usually an adequate foundation material for a coal refuse embankment. However, an evaluation of foundation rock conditions should be performed, since troublesome layering or discontinuities and localized weaknesses may be present. Seepage and uncontrolled discharge of leachates through fractures in foundation or abutment rock can be a significant problem, especially for impounding facilities. Sections 6.6.5 and 8.9 discuss methods for preparing rock foundations and abutments for construction of embankments.

Not all rock characteristics may be apparent following the geotechnical exploratory drilling and laboratory testing performed as part of facility design. Thus, it is highly desirable that the foundation surface be inspected by a geologist or geotechnical engineer after the foundation has been exposed by excavation. This will allow final confirmation of the embankment design prior to construction. If special provisions associated with rock foundations are needed, they will typically involve control features such as impervious soil blankets, localized grouting, shotcrete placement, or preparation of a planned contact between clayey soils and rock. Section 11.6.6.1 discusses the placement of impervious blankets. Foundation grouting of rock formations to cut off or minimize seepage through fractures is discussed in Fell et al. (2005) and USACE (1984a).

#### 11.6.3.5 Mine Spoil

Mine spoil may be present in the foundation of the area planned for coal refuse disposal, either as remnant materials from past mine operations at the site or as a result of planned surface mining and refuse disposal. Evaluation of the mine spoil characteristics and associated foundation preparation requirements should be addressed in the refuse disposal facility design. Characterization of the mine spoil properties and the potential for use of mine spoil in construction along with the possible need for removal, densification, and seepage/internal erosion control should also be addressed. Section 8.8 presents design and construction considerations associated with mine spoil. State regulations may limit the use of mine spoil at a refuse disposal facility.

If unanticipated spoil materials are encountered, they should be thoroughly characterized to determine if they are suitable for incorporation into the foundation at an impounding coal refuse disposal facility.

### 11.6.4 Water Control

Control of water in relation to the development of coal refuse disposal facilities falls into four basic categories:

1. Control of flood water by storage capacity combined with spillway and decant structures for impoundments and by diversion ditches for non-impounding embankments
2. Control of seepage through and under the refuse embankment (from springs/groundwater and from impounded water)
3. Control of natural stream flow and storm runoff during construction when permanent facility hydraulic structures are not completed
4. Control of site drainage from storm runoff

The first category of water control structures refers to hydraulic structures associated with conveying watershed runoff through or around the coal refuse disposal facility. Design requirements for these structures are presented in Section 9.7, and construction requirements for these features are discussed in Section 11.7.

The second category of water control structures refers to internal drains for collection and control of springs in the foundation area, seepage from an impoundment, interception of leachates, and control of the phreatic level in the embankment. Design requirements for filters and drains are presented in Section 6.6.2.3.1, and construction requirements are discussed in Section 11.7.

The third category of water control is often referred to as a "diversion" and may be required during facility construction. A diversion can be as simple as installing a small drainage culvert under a haul road or as complex as construction for passing a stream around a site prior to completion of permanent facility hydraulic structures. For coal refuse disposal, diversions may be required on several occasions during the operational period of the facility as, for example, the perimeter ditch system at a valley fill is upgraded to match the advancing refuse embankment. Temporary diversions should be designed and constructed consistent with the risk associated with failure during the time of use (i.e., the shorter the period of time required for diversion, the smaller the design storm requirement, consistent with regulatory requirements). Permanent diversion ditches should be designed as long-term drainage channels. Typical design criteria for stream diversions are presented in Chapter 9.

Diversion requirements discussed in Chapter 9 include:

- Inlet and outlet sections sized to handle expected flows and designed without obstructions or sharp angles
- Transport section alignment and grade
- Freeboard design for preventing overflow to areas that must be protected
- Design for prevention of erosive damage through material selection and energy dissipation control

Planning, scheduling and construction of diversions should reflect requirements for continued refuse disposal and other site related activities. Access across open diversions may be difficult, especially where permanent stream flows are being conveyed. Light-gauge, temporary culverts may be capable of passing the required flow. However, heavy equipment passing over such culverts can cause damage if they are inadequately designed and constructed.

Although material selection for temporary diversions is not as important as for permanent hydraulic structures, strength, erosion and corrosion issues must be considered. Further discussion of these topics is provided in Section 9.7.3 and Section 11.7.

The fourth category associated with water control is related to on-site drainage for handling storm runoff. This type of water control generally includes grading of embankment surfaces and construction of conveyance and collection structures. Temporary and final embankment surfaces, including the active work area for refuse placement, must be graded such that runoff is directed toward conveyance channels and that ponding and saturation of the fill is minimized. This is typically accomplished by specifying surface grades of at least 1 percent and controlling the placement of lifts so as to maintain a positive gradient toward the perimeter of the embankment where the runoff is collected and conveyed from the area in channels. The channels then convey site runoff to sedimentation traps or ponds for clarification before release. These drainage control features should be incorporated into the facility plans and specifications. The design of site drainage structures is addressed in Chapter 9.

A critical element in control of on-site drainage is the actual process of coarse refuse placement. Lift placement (typically end-dumped piles placed by trucks) and spreading to a uniform thickness for compaction is dependent upon a working surface that can support construction traffic and is not excessively wet or does not have standing water that would interfere with the compaction effort. If each lift is advanced uniformly across the entire active working surface, the surface gradient to drainage channels is maintained. Also, when periods of sustained inclement weather occur that adversely impact the working surface, it is useful to grade and seal the working surface so that it sheds water and to have other non-critical areas for short-term disposal.

Mobile conveyor systems are sometimes employed to deliver coarse refuse directly to the working surface, with dozers, loaders and trucks used to spread the lift materials. Mobile conveyor locations and equipment selection should reflect the need for advancing lifts uniformly across the working surface to maintain the drainage gradient.

### 11.6.5 General Excavation

Excavation is required for construction of diversions, minor drainage ditches and channels, trenches for internal drains and control of natural springs, major decants or spillways, embankment foundation development, liner construction, haul and access road construction, and other site operations. Many of these earth-moving activities have already been discussed. However, certain precautions should be taken for excavations at coal refuse disposal sites.

Many coal refuse disposal facilities are located in mountainous areas. It follows that some excavations associated with facility development at these sites will result in steep, side-hill cuts. In making such excavations, care should be taken to disturb as little vegetation as possible, particularly on the uphill side of drainage ditches. This is especially important if the cut being made is for the construction of a permanent drainage channel. The stability of slopes above drainage channels is crucial to their performance during storms. Vegetation, especially in the form of trees with extensive root systems, helps to maintain slope stability of steep natural hillsides and also aids in minimizing the potential for erosive movement of soil into the channel and consequent blocking or reduction of flow capacity.

Stability of excavated slopes, whether the excavation is permanent or temporary, can be achieved by decreasing the angle of the cut or by bracing the exposed surface. Only if excavations are in sound, competent rock should vertical cuts be made. Steeply-sloped excavations in clayey soils may appear stable at the time of excavation, but sudden collapse, especially during rainy weather, can occur. Safety regulations such as those developed by OSHA for providing safe conditions in and around open excavations should be strictly followed. Slope stability issues are discussed in more detail in Section 6.6.4.

### 11.6.6 Embankment Fill Constructed from On-Site Borrow Materials

Starter embankments for impounding facilities are frequently constructed from on-site borrow materials. At some coal refuse disposal facilities, coarse coal refuse may not be available in sufficient quantities or with adequate properties for all embankment fill requirements. Combined coarse and fine refuse may be difficult to compact to the density and strength required for structural fill. Also, as discussed in Chapter 6, an impervious earth core or cutoff may be needed within the refuse embankment or as an upstream blanket for controlling seepage and water pressure. These considerations may necessitate construction of a zoned embankment with design implications as discussed in Sections 5.1 and 6.3.1.2. Borrow materials may also be needed for fills and embankments associated with mine seals and barriers. For any of these situations, use of on-site sources may be necessary. While borrow materials generally can be characterized as “clayey and silty” or “rock and granular,” mine spoil materials may exhibit both types of characteristics.

#### 11.6.6.1 Clayey and Silty Borrow Materials

If fine-grained borrow materials such as clays or silts are to be placed in zones as part of embankments or for seepage control (impervious blankets and cores), major considerations during construction include:

- Material properties such as grain-size distribution, water content, densities, strength, hydraulic conductivity, etc.

- Material availability in sufficient quantities, preferably located near the construction site
- Equipment required for loading, transporting and placing the material
- Lift thickness during placement
- Equipment required for compaction and appropriate compaction procedures

Detailed discussions of earth-fill operations can be found in Sherard et al. (1963), Church (1981), USACE (1995b) and USBR (1998). Some general comments regarding the distribution and placement of clayey and silty borrow materials (for structural fill and impervious blankets and cores) are:

- The material may be difficult to remove from the borrow areas. If scrapers are used to excavate earth borrow of this type, an additional tractor may be required.
- The material should be placed in relatively thin lifts. Sherard et al. (1963) recommended approximately 6 to 9 inches. If thicker lifts are used, the required density may not be achieved throughout the full depth of the lift.
- Compaction equipment used for clayey or silty soils is typically of the segmented-pad or tamping-foot type, commonly referred to as a sheepsfoot roller. Vibration does not significantly improve the compaction of these soils.
- The compactability of clayey and silty soil is very sensitive to moisture conditions. In most regions, borrow areas should be graded to shed surface water, and fill areas should be sloped to drain. In dry regions, moisture may have to be added to the borrow material. Sealing of fill areas by rolling with smooth-wheeled vehicles or non-vibrating, smooth-drum rollers is recommended if precipitation is anticipated. USBR (1998) and Church (1981) provide discussions of embankment construction and moisture control.
- If the borrow material water content is too high to permit adequate compaction, drying may be required. Drying can sometimes be accomplished by disking and allowing the sun and wind to remove the moisture.
- Placement and compaction of fill for impervious blankets and cores in winter weather is always difficult and is essentially impossible if the soil is frozen. Operations should be scheduled to avoid fill placement during periods of adverse weather conditions.

The above discussion relates primarily to embankment zones where strength is a major factor. If borrow material is being used for seepage control such as an impervious core within the embankment or an imperious blanket in the valley bottom, it is essential to obtain a uniform, non-layered clayey or silty soil consistency. In such applications, the borrow material should be placed a few percentage points wetter than optimum water content if the material can meet the associated strength requirements and is in accordance with the construction specifications. This should result in a homogeneous mass flexible enough to accept deformation without cracking. Further discussion of this subject is provided in Section 6.5.3.

### 11.6.6.2 Rock and Granular Borrow Materials

Many considerations for use of rock or granular borrow material for structural fill are similar to those mentioned above for clayey or silty borrow material. However, the handling and compaction equipment needed, acceptable lift thicknesses, and material properties are different.

Rock-fill material is generally handled by large excavators and haul trucks, and granular borrow material can be handled by scrapers if large boulders are not present. Quarrying hard rock may require explosives and blasting, but removing soft weathered rock may only require a powerful dozer with ripper teeth. Church (1981) discusses the various dozer attachments available for ripping and their applications.

The wear on equipment used for handling rock and granular materials is significant. Steel tracks on dozers require frequent replacement. Rubber tires are easily cut by sharp rock edges and require frequent replacement, although replaceable chain guards can be used to reduce damage. Special armor plating is needed for the bodies of trucks that haul rock and coarse granular materials.

Acceptable lift thicknesses for rock and granular material are much greater than for fine-grained soils, provided that increased compactive effort is applied. USBR (1998), USBR (1987a) and Sherard et al. (1963) recommend a lift thickness of one to two times the maximum rock diameter for rock fills that contain fines, while USACE (1995b) recommends that lift thicknesses for rockfill dams be no greater that 24 inches unless test fills show that adequate compaction can be obtained using thicker lifts. This guidance may require modification for mine spoil conditions where large rock on the order of the lift thickness may inhibit densification of surrounding spoil or where uniform gradation or maximum hydraulic conductivity characteristics are critical. In situations where the largest dimension of rock in the fill approaches the desired lift thickness, the interstices around the rock should be filled with finer materials and compacted until there is no visible evidence of consolidation of the material being compacted. The recommended lift thickness for gravel is about one foot, but this can be increased to two feet or more if the gravel is coarse. Vibratory compactors are very effective on rock and clean granular fill and may allow even higher lift thicknesses. The type and size of vibratory compactors required depends on the borrow material characteristics and lift thickness.

The water content for rock and granular fill is relatively unimportant. However, wetting of rock and clean gravels used for compacted fill will minimize friction between contact points of adjacent particles, allowing them to approach maximum density with reduced compactive effort.

Density controls for rock and granular fills are not as precisely defined as for fine-grained soils, and use of a method specification (i.e., minimum number of passes by construction equipment) based on site-specific observations may be appropriate. It is relatively difficult to take accurate in-place density tests for rock fills, as discussed in Section 11.8. Careful observation of the action of compaction equipment is an important part of evaluation of the effectiveness of the placement and compaction process. Key points to watch for include the following:

- Compaction efforts should continue until no further decrease in the lift thickness is observed during a pass of the compaction equipment.
- When compaction is complete, loose fine particles on the surface near the compaction equipment bounce due to vibrations transmitted through dense fill.
- When compaction is complete, the edges of adjacent rock particles will be crushed from being wedged into a tight position. Further compactive effort will only increase the amount of crushing rather than significantly increase the density. If the presence of crushed rock particles reduces desired drainage, compaction should be closely observed and terminated when crushing begins to occur.

#### 11.6.6.3 Use of Mine Spoil

Mine spoil may be an acceptable borrow material for use in refuse disposal embankments, including structural zones, provided that the material characteristics are identified and accommodated in the design and construction. Mine spoil may include substantial portions of fine silt and clay materials, but typically is predominantly granular materials and large rock. Accordingly, in a zoned embankment, more pervious mine spoil would be placed downstream of less pervious embankment materials such as coarse refuse. Key issues are the consistency of the spoil borrow source material and measures that need to be implemented so that it meets design requirements. Internal erosion of finer material into mine spoil is a particular concern. Characterization, design, and construction considerations of mine spoil are presented in Section 8.8.

Characterization of mine spoil can be accomplished by: (1) review of the mine overburden geology, (2) use of exploration test pits and borings to obtain samples for testing, and (3) performance of geophysical surveys to determine density and shear-wave velocity. The durability of the spoil material should be evaluated; in particular drainage and grain-size characteristics are important. Use of larger specimens for laboratory testing to obtain a representative sample may be needed. Measures that may be necessary during construction include segregation of large rock (using screens or in some instances during lift placement using dozers and graders) and rigorous quality control testing to verify material properties. Additionally, it may be desirable during mining operations that will provide borrow material, to strip and segregate soil and some rock strata (e.g., shales) from more durable rock strata for subsequent use.

## 11.7 FACILITY APPURTENANT STRUCTURES

Facility appurtenant structures generally require materials and construction procedures that are different from those for the disposal of refuse. These structures generally include, but are not limited to:

- Internal drainage systems in the refuse embankment such as internal drains, drainage trenches, etc.
- Spillways, decant structures and other major hydraulic control structures
- Minor surface drainage structures such as collection ditches, erosion control devices and culverts
- Haul and access road bridges and miscellaneous buildings associated with refuse disposal operations
- Mine-opening/auger-hole seals and drains

Discussion of material requirements and construction procedures for various types of appurtenant structures is provided in the following pages.

### 11.7.1 Material Requirements

The potentially corrosive nature of some coal refuse or leachates from the coal refuse makes material selection important if the appurtenant structures are to function as intended for long periods and into abandonment. Table 11.6 presents the most common construction materials used for facility appurtenant structures, shows the corrosive or deterioration mechanism for each material, and indicates protective measures that may be taken.

Coal refuse, and particularly leachate water therefrom, should be chemically tested for corrosive components. Typically, leachates will be acidic (low pH value) and will contain sulfates that cause corrosion of many materials. Coal refuse varies significantly, and testing is advisable prior to identifying appropriate protection measures at a particular disposal facility.

### 11.7.2 Filters and Drains

Control of water flowing across a disposal site, or seeping through an embankment or its foundation, is an important factor in satisfying both safety and environmental requirements. Design requirements for limiting, controlling and collecting these flows are presented in Section 6.6.2.3.

## TABLE 11.6 EFFECTS OF CORROSION AND COUNTERMEASURES

| Facility Component | Materials and their Corrosive or Deterioration Mechanism | Protective Measures |
|---|---|---|
| I. Internal Drainage Systems | | |
| A. Bank run gravels and sands or crushed rock | Sandstones: If the bonding agent between sand grains is silt particles or clay flakes consisting of calcite ($CaCO_2$), sandstones will be attacked by acidic leachates. | Use only corrosive resistant sandstone with silica bond ($SiO_2$). |
| | Limestones: Mineral calcite ($CaCO_3$) will be dissolved by acidic leachates. | Do not use in internal drainage system. |
| | Shale: Silt and clay composition breaks down when subjected to weathering or moisture. | Do not use in internal drainage system. |
| B. Geosysnthetics | Nylon, Polypropylene, Polyester, HDPE, PVC: Good corrosive resistance. | Most materials are sensitive to excessive heat. Protection from ultraviolet light is necessary prior to installation. |
| C. Drainage and transport pipes | Steel and Corrugated Metal: See discussion of metal products, Item III below. | Galvanizing and/or coating with asphaltic or epoxy protective material or coal tar. Asphaltic and coal tar coatings are susceptible to damage. Asphalt and coal tar pipes are not recommended in critical situations. Properly designed epoxy-coated steel pipes can be considered for critical situations.<br><br>Use thick-walled pipe to account for corrosion; applicable if rate of corrosion is relatively low.<br><br>Cathodic protection in vulnerable areas.<br><br>Use special alloy steels, stainless or other, (See discussion of Metal Products under Item III). |
| | Cast Iron: Same as steel, but corrosion may form protective coating on metal under ideal conditions. | Coating with asphaltic protective material or coal tar. Coating is susceptible to damage and is not recommended in critical situations. |
| | | Use thick-walled pipe to account for corrosion; applicable if rate of corrosion is relatively low. |
| | | Cathodic protection is required in vulnerable areas. |
| | Plastic (General): Excellent corrosion resistance. | Consideration should be given to the compatibility of plastic pipe materials with bedding preparations and backfill. |

TABLE 11.6 EFFECTS OF CORROSION AND COUNTERMEASURES (Continued)

| Facility Component | Materials and their Corrosive or Deterioration Mechanism | Protective Measures |
|---|---|---|
| C. Drainage and transport pipes (Continued) | Polyethylene (PE): Excellent for corrosive liquid transport and backfill. | Check characteristics and strength for the density PE pipe considered. Outside diameter controlled HDPE, when properly designed, can be used in critical situations. |
| | ABS: Good corrosion resistance. | Check characteristics and strength of ABS pipe. |
| | PVC: Good for use with corrosive solutions below 140°F, brittle at low temperatures. | Do not use when temperature above 140°F may be contacted. Check allowable application of specific PVC type used. |
| | Concrete: See discussion on Concrete Structures, Item II below. | |
| | Thermosetting: Epoxy and polyester resin reinforced (fiberglass and filament wound) and non-reinforced pipe. | Check properties of specific resin used for strength, temperature effects and corrosion resistance. |
| D. Gates and miscellaneous metal work | See discussion of Metal Products under Item III. | |
| II. Concrete Structures (spillways, decant structures, channels, outflow conduits, etc.) | | |
| A. Cement | The bonding agent in ordinary concrete (hydrated Portland cement) leaches when exposed to acidic waters. | Use Type II or IIa cement for contact with water containing (100 to 150 ppm) sulfates as $SO_4$. |
| | Sulfates in water or refuse react with tricalcium aluminate in cement causing swelling and disintegration of concrete. | Use Type V cement for contact with water containing greater than 1000 ppm of sulfates as $SO_4$.<br><br>Provide coatings for concrete structures as discussed in ACI (2005) Committee 515 report.<br><br>Low water-cement mix ratios result in less permeable concrete thus reducing penetration of water-containing, deleterious compounds. Air entrainment and other additives are also recommended for increasing resistance to water penetration and improving workability of low-water cement mixes.<br><br>Replace concrete materials with materials that are less susceptible to deterioration (e. g., coated cast-iron pipe in place of concrete pipe). |

TABLE 11.6 EFFECTS OF CORROSION AND COUNTERMEASURES
(Continued)

| Facility Component | Materials and their Corrosive or Deterioration Mechanism | Protective Measures |
|---|---|---|
| B. Aggregate | See discussion of bank-run gravels or crushed rock, Item I.A. | |
| | See also ACI (2005), ACI Committee 201 for reactive aggregates. | |
| C. Reinforcing steel | See also discussion of metal products under Item III. | |
| | Porous concrete or inadequate cover permits rapid attack on reinforcing steel. Corroding steel causes expansion, disintegrating the concrete. | Typical concrete cover may protect reinforcing steel if corrosive environment is not severe. For severe environments and long service life, epoxy-coated rebar may be considered.<br><br>Provide coatings for concrete structures as discussed in ACI (2005).<br><br>Low water-cement mix ratios result in less permeable concrete and thus provide greater protection against corrosion. Air-entrained concrete is recommended as an aid to placement and for increased resistance to water penetration. |
| III. Metal Products (gates, valves, outflow conduits, decant pipes, etc.) | | |
| A. Steel | Electrochemical corrosion caused by oxidation in an ionizing medium (water). Rate of corrosion is governed by environmental factors such as hydrogen ion concentration, oxygen concentration, and temperature. For pH between 6.5 and 8.0, corrosion protection is probably not required. | Use internal and external coatings such as asphalt, coal tar, epoxies or other non-reactive materials.<br><br>Provide cathodic protection. Use sacrificial anodes to reduce corrosion.<br><br>Use thicker material in construction to account for deterioration; applicable if rate of corrosion as determined from bench or field studies is relatively low.<br><br>Use special-alloy steels, stainless or other. |
| | Corrosion caused by reaction with dissolved, ionized or colloidal substances in the corroding medium (water) such as: $H^+$, $0_2$, $C0_2$, $NH_3$ (bacteria), $S0_4^{-2}$, $S^{-2}$, Cl. | Use of internal and external coatings such as epoxy, asphalt, coal tar, epoxies or other nonreactive materials.<br><br>Provide cathodic protection. Use sacrificial anodes to reduce corrosion of metal product to be protected.<br><br>Use thicker material in construction to account for deterioration; applicable if rate of corrosion as determined from bench or field studies is relatively low.<br><br>Use special-alloy steels, stainless or other. |

The material and construction issues associated with design implementation are discussed in the following subsections.

#### 11.7.2.1 Granular and Geotextile Filters

Filters consist of granular materials placed against disposed coal refuse or earth fill where seepage is likely to exit, or between materials of greatly different particle size (e.g., between clayey silt and coarse coal refuse) where seepage flows from the smaller-particle-sized material to the larger-particle-sized material. The primary purpose of a filter is to allow movement of water without allowing fine particles to exit or to move into the coarser material void spaces. Such movement could lead to internal erosion and weaken the fine material. Internal erosion can create voids in an embankment, increase rates of seepage and cause eventual failure. Movement of finer particles can also obstruct the flow within the coarse material. Granular filters may consist of multiple layers. The gradation of each layer should be sized such that finer granular material is unable to enter coarser layers and cause clogging. Geosynthetic materials such as geotextiles can be used in single layer applications or sometimes in combination with granular materials to create multiple layers. Layered granular and/or geotextile systems are commonly used in filter diaphragms and internal drains in slurry impoundment embankments. The National Dam Safety Review Board (NDSRB), which comprises federal agencies that deal with dam safety, recommends that a geotextile not be used as a filter for a critical internal drain in a water impounding dam unless it is accessible in the event that it does not perform as intended.

Granular filters should be composed of durable free-draining granular materials. Section 6.6.2.3 discusses design requirements for grain-size distribution. Filter materials typically should not contain more than five percent clay- and silt-size particles, either before or after placement. Similarly, geotextiles should be designed based on the grain-size distribution of the soil or refuse and apparent opening size of the geosynthetic material. Design requirements and limitations for geotextiles, including guidance for evaluating the potential for chemical and biological clogging, are presented in Section 6.6.2.3.2. Construction-related guidance for installation of geotextiles for filters includes:

- In preparing surfaces for geotextile placement, depressions, holes, and voids should be filled so that the geotextile sheet is continuously supported. The geotextile should be placed to loosely drape the surface with no sagging between surface contact points. Continuous contact between the geotextile and the support material is considered critical in addressing clogging potential (Talbot et al., 2000). Geotextile 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 rock as a bedding layer or protection buffer.
- Geotextiles should be secured by sewing, pins, staples, or weights so that specified overlaps are maintained during construction.
- Adjacent geotextile sheets should generally be placed with upstream layers overlapping downstream layers.
- In placing material on a geotextile, care must be taken to avoid punctures or tears. The construction specifications should limit the size and drop height of rocks to be placed on the geotextile. Generally, stones weighing more than 250 pounds should be placed with no free fall. Field trials should be made to verify that no damage will occur due to the rock placement procedures, or a cushion layer of finer material may be utilized to protect the geotextile.
- Geotextiles should be covered or protected as soon as possible to prevent degradation or damage from exposure or equipment traffic and to prevent fines from accumulating on the fabric. Manufacturer recommendations relative to exposure should be followed.

Geosynthetic materials are commonly used as filter layers for drainage systems at a refuse embankment and as separating and reinforcing layers for channel linings and haul roads. Similar to granular filters, a geosynthetic material will allow the movement of water while preventing fine particles from entering the voids of a coarser drainage medium. Properties of filtering geosynthetics such as permittivity, hydraulic conductivity, percent open area and apparent opening size must be evaluated as part of drainage system design. Where geosynthetics are employed at internal drainage structures for impounding embankments, performance tests (e.g., gradient ratio test) should be conducted using actual embankment materials. Separating and reinforcing geosynthetics are normally chosen based upon their strength properties such as puncture strength, grab tensile strength, wide width tensile strength, grab tensile elongation, and trapezoid tear strength. Manufacturers' construction guidance for geotextile filters should also be followed when geotextiles are used as a separation layer.

Care should be taken during construction to prevent runoff from washing fine particles into an unprotected filter. Filters should be constructed to an elevation slightly above that of adjacent materials. If this is not practical, diversion ditches should be constructed or temporary coverings should be placed over the filter.

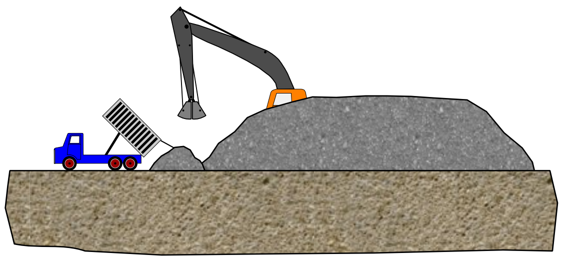
Filter materials should be stockpiled, handled and placed in a manner similar to material used for underdrains, as discussed in the following paragraphs.

#### 11.7.2.2 Granular Underdrains

Underdrains typically consist of trenches filled with granular material, granular blankets, or granular collection zones along stream bottoms in valleys or at isolated seeps or springs. These drains can be constructed with or without perforated pipes for conveying seepage from the collection zone to a safe exit location. The granular zones are generally thin, and typically there are no compaction specifications for the granular material; however, where more extensive granular zones are present, such as with chimney drains, provisions for placement should be provided.

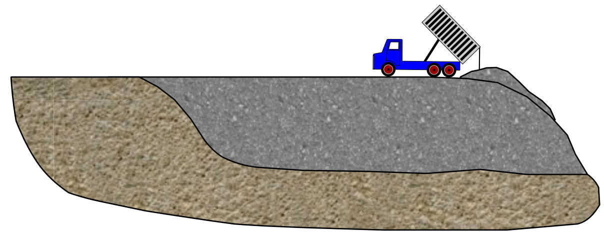
Granular drains or collection zones must remain free-draining. Therefore, drain materials should be selected to: (1) allow flow and act as filter protection for adjacent material (Section 6.6.2.3), (2) resist deterioration over time, and (3) resist deterioration due to chemical attack. Table 11.6 lists possible effects of chemical attack or weathering on gravels and crushed rock that might be used as granular drainage materials. Granular aggregate used for underdrains and filters should be obtained from reputable suppliers or verified borrow sources. To minimize the potential for degradation, rock used in granular drains should have high durability; applicable rock testing for durability is discussed in Section 6.5.9.4. It is particularly important to avoid the use of most limestone because of the possibility for generation of acidic leachates that can react chemically causing dissolution or degradation. As a quick field test, the presence of limestone in granular material can be determined by placing a dilute solution of hydrochloric acid on the material. If an effervescent or fizzing reaction occurs, the material should not be used. Laboratory test data for both the refuse and the potential drain material should be carefully reviewed prior to the purchase or use of any drain material.

Granular material must not be allowed to segregate prior to placement. Figure 11.5 shows correct and incorrect ways of stockpiling and handling granular materials. The stockpile location and materials handling procedures should be such as to prevent siltation contamination by the loading or unloading equipment or by wind- or water-carried particles. Well-graded materials should not be dropped or allowed to roll down a slope for any significant distance, because the larger particles will separate from other materials by moving to the outside of the pile as they roll down the slope.



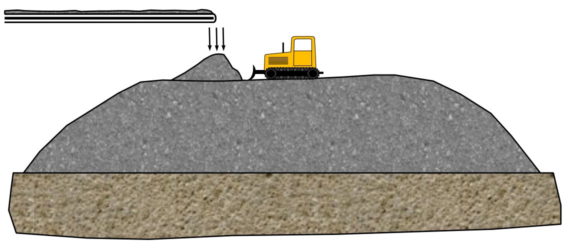
PREFERABLE

CRANE OR OTHER MEANS OF PLACING MATERIAL IN PILE IN UNITS (NOT LARGER THAN A TRUCK LOAD) THAT REMAIN WHERE PLACED AND DO NOT RUN DOWN SLOPES.



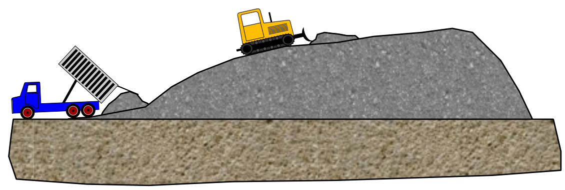
OBJECTIONABLE

METHODS THAT PERMIT THE MATERIAL TO ROLL DOWN THE SLOPE AS IT IS ADDED TO THE PILE OR PERMIT THE HAULING EQUIPMENT TO OPERATE OVER THE SAME SURFACE REPEATEDLY.



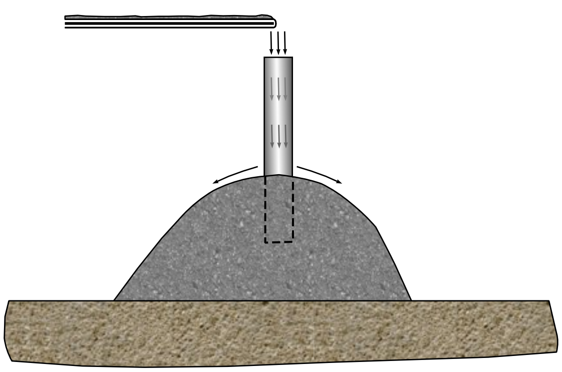
LIMITED ACCEPTABILITY

PILE BUILT RADIALLY IN HORIZONTAL LAYERS BY BULLDOZER WORKING WITH MATERIALS DROPPED FROM A CONVEYOR BELT.



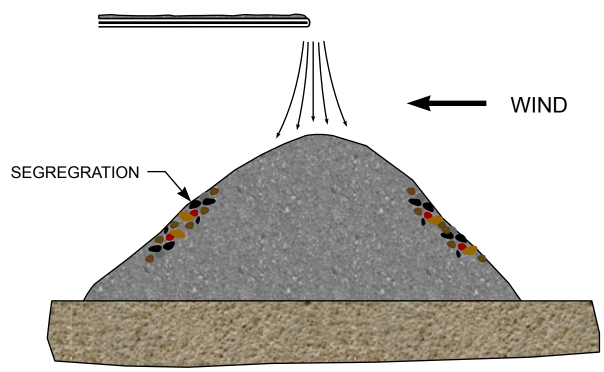
GENERALLY OBJECTIONABLE

UNLESS MATERIALS STRONGLY RESIST BREAKAGE, STACKING PROGRESSIVE LAYERS ON SLOPE NOT FLATTER THAN 3:1.



CORRECT

CHIMNEY SURROUNDING MATERIAL FALLING FROM END OF CONVEYOR BELT TO PREVENT WIND FROM SEPARATING FINE AND COARSE MATERIALS. OPENINGS PROVIDED AS REQUIRED TO DISCHARGE MATERIALS AT VARIOUS ELEVATIONS ON PILE.




INCORRECT

FREE FALL OF MATERIAL FROM END OF STACKER PERMITTING WIND TO SEPARATE FINE FROM COARSE MATERIAL.

FIGURE 11.5 STOCKPILING AND HANDLING OF GRANULAR MATERIALS

If granular drains must be placed in thick layers, or are critical to the stability of the embankment because of their position, the guidance in Section 11.6.6.2 relative to the placement and compaction of rock and granular fill should be reviewed prior to granular drain construction. Should compaction be necessary, the construction specification should account for potential breakdown of the granular material.

#### 11.7.2.3 Drainage Pipe

Drainage pipes are often placed in portions of the refuse embankment to convey water from the granular drains (internal or surface drains) to an acceptable exit point. Within the collection zone, drainage pipes are normally perforated to facilitate inflow of water that collects in the drain. The remainder of the drainage pipe may or may not be perforated. Drainage pipes should be constructed from a material resistant to chemical attack by refuse leachates and should be sized according to flow capacity and structural requirements. They should generally be designed and installed such that they are self-cleaning and the potential for accumulation of fine material in the pipe is minimized.

Although corrugated metal pipe (CMP) can often be protected by coatings, the potential for coating damage during installation is a potential problem. Since plastic pipe is not normally susceptible to corrosion from acids, it is often more suitable than CMP for drainage pipes in coal refuse.

When perforated pipe is placed, the perforations should normally be placed facing downward. This causes the water to flow up into the pipe, minimizing the chance for transport of fines into the pipe and consequent reduction in flow capacity. Instructions from the pipe manufacturer are often explicit in this respect and should be followed. For most perforated pipe, several rows of perforations are normally provided around the circumference of the pipe. For this type of pipe it will not be possible to orient all of the perforations facing downward. For installation in very fine materials, a double layer filter and granular drain may be needed to prevent fine material from entering the perforations. Such requirements should be detailed in the facility plans and specifications.

Drainage pipes beneath embankments should be designed to withstand the loading of the embankment, with specification of pipe support and backfill that prevents point loading on the pipe. Design and construction of conduits for dams was published by FEMA (2005a), and additional guidance by FEMA related to plastic pipe has also been published (FEMA, 2007). During construction, sufficient fill must be placed over the pipe before traversing it with heavy equipment. Manufacturers' recommendations should be checked.

### 11.7.3 Culverts and Decants

Conduits are often used for transporting decanted impoundment water and flood water beneath embankments and also for culvert-type spillways. Conduit materials should be selected on the basis of strength and resistance to corrosion. Potential corrosion and deterioration mechanisms for conduit materials are discussed under Item I-C (Drainage and transport pipes) in Table 11.6. Progressive deterioration of large conduits that are critical to refuse facility hydraulic systems is not acceptable, and effort should be made to prevent loss of conduit flow capacity, leakage that can lead to material infiltration or exfiltration, and structural distress.

Conduits require special bedding or thrust blocks at turns. Uniform contact around and under the conduit is essential, particularly at thrust- block areas. When conduits associated with decant systems and culvert spillways are installed in critical areas, such as through impounding embankments, special provisions are required for performing compaction beneath and around the conduit to minimize the potential for seepage along the exterior of the pipe. Compaction beneath the haunches of the pipe is difficult and normally can not be accomplished unless special materials and designs are employed. Concrete cradles and sand bedding have been used to improve the support beneath and around conduits.

Other more specialized materials and methods such as use of flowable backfill or the cut-earth cradle method can be employed for conduit installation. Flowable fill, or controlled low-strength material (CLSM), is a low-strength, fine-aggregate concrete with unconfined compression strengths between 50 and 200 psi. The use of flowable fill to backfill a conduit trench and serve as bedding for the conduit provides firm support extending from the spring line around the base of the conduit. Flowable fill has the added benefit of having low hydraulic conductivity. The mix must be designed to prevent shrinkage and to have satisfactory strength/deformation characteristics, as discussed in Sections 6.5.10.2 and 6.6.6.3.3. Either shrinkage or cracking of flowable fill will allow a flow path for seepage.

The cut-earth cradle method involves compaction of select material at the base of the conduit location and subsequent excavation using a specialized attachment on an excavator resulting in a semi-circular cradle excavation. The cradle excavation is sized and shaped so that it closely fits the conduit. A material such as bentonite powder has been used to compensate for small, discontinuous gaps between the cradle and the pipe. The depth of the cradle should be approximately one-half the diameter of the pipe. This method requires a high level of quality control in order to prevent a flow path from occurring along the pipe.

To collect and discharge any possible seepage along the conduit in a controlled manner, a filter diaphragm is recommended regardless of the method employed for conduit backfill and support.

### 11.7.4 Concrete Structures

Coal refuse disposal facility appurtenant structures that may be totally or partially constructed of concrete include spillways, decant structures, culverts and drainage channels, as well as foundations for various small structures. Such concrete work is not unique to coal refuse disposal facilities, and most applications are extensively discussed by the ACI (2007), the USBR (1992b) and in numerous concrete design textbooks.

Chemical attack and deterioration and related preventative measures are key considerations in the use of concrete for any facility structure that may be in contact with coal refuse or leachates from coal refuse. Table 11.6 presents a summary of major considerations. Although acidic leachates are an obvious corrosive environment, it is emphasized that for concrete durability it is also important to guard against the sulfates common to coal refuse and coal refuse leachates. The USBR (1987a) shows typical examples of sulfate attack and discusses methods for retarding it.

Before specific protective measures for concrete exposed to coal refuse and leachates are selected, the acidic potential and sulfate contents of the refuse should be evaluated. Chemical testing is recommended. Concrete structures exposed to natural ground adjacent to coal refuse disposal facilities should also be protected from deterioration by chemical attack. Groundwater in and around coal refuse may contain corrosive elements and can cause concrete deterioration even if the concrete is not in direct contact with coal refuse.

Minimum practices and protective measures for concrete used in or near coal refuse disposal facilities should include:

- Use of sulfate-resistant cement (preferably Type V, but in some mine environments Type II cement will suffice). Depending on cement availability, Type II or Type I cement in combination with pozzolans (e.g., fly ash, slag cement) may provide adequate sulfate resistance.
- Low water-cement ratios and relatively rich mixes should be used so that dense, high-strength concrete results.

- Air entrainment should be used to increase the workability of low water-cement ratio mixes and to decrease the hydraulic conductivity of the hardened concrete. The use of other water reducing chemical additives to allow further reduction of the water-cement ratio and to provide increased strength should also be considered.
- Extra cover concrete should generally be provided over all reinforcing steel.
- Fresh concrete should be thoroughly vibrated to maximize densification and to eliminate honeycombing.
- Concrete should be thoroughly cured to maximize strength gain.

Many protective coatings discussed in the following section are also applicable to concrete structures, although application and maintenance may be more difficult than for application to metals.

### 11.7.5 Gates, Valves, Pipelines and Other Metal Work

Metal work in and around a coal refuse disposal facility must be protected against corrosion from chemical attack. Special alloy steels may offer good protection against corrosion, but their selection should be made with care because some types of alloy steels are actually more susceptible to attack from certain chemicals than regular construction grade carbon steels. The cost of many alloy steels is similar to carbon steel, but cost must be evaluated on a case-by-case basis. Table 11.6 summarizes various types of chemical attack and corresponding measures for protection.

Installation of metal products with protective coatings is common, but installation should be accomplished in strict accordance with the recommendations of the coating manufacturer. Various coatings are available that will provide adequate protection if the integrity of the coatings is maintained during construction and operation. Coatings should be: (1) continuous, (2) not support bacterial growths or absorb water, and (3) not deteriorate with time. Epoxy coatings are very durable and provide excellent protection against corrosion and bacterial growth. However, field application of epoxy coatings is difficult and requires special surface preparation per the manufacturer's recommendations. Coal tars meet all of the coating criteria and are one of the best bituminous materials available for protection of steel surfaces. Asphalt coatings are an alternate low-cost bituminous coating. However, if bituminous coatings are scratched or damaged during installation, they must be repaired prior to completion of the installation.

Special vinyl chloride or chlorinated rubber coatings are also available for corrosive protection. Application of these coatings must be made in strict accordance with recommendations of the manufacturer, as there are significant differences in methods of application.

Imperfect coating of metal may actually lead to more rapid deterioration than no coating at all. This can occur where galvanic action is very strong. If the predominant portion of the metal is protected by materials that resist electrical currents, galvanic action will concentrate at points of imperfection, leading to very rapid removal of the metal at these locations. Protection against this type of corrosion requires installation of a sacrificial anode designed by a professional experienced in corrosion protection. USACE (1985) and USACE (2004) provide background information and guidance on testing and design for cathodic protection.

### 11.7.6 Support Structures

Offices, maintenance buildings, loading bins, etc. should be built in accordance with applicable building codes and generally accepted construction practices. Coal refuse can often be used effectively for structural fills on which such structures are constructed. The same precautions against material deterioration due to acid or sulfate attack should be taken. Drainage and utility pipes, foundations and electrical conduits are all subject to corrosive action if exposed to coal refuse or coal refuse leachates.

### 11.7.7 Mine-Opening and Auger-Hole Seals and Drains

Depending upon their location within an embankment or impoundment area, the presence of mine openings and auger holes in coal seams should be addressed with backfilling, barriers, bulkheads, seals or drains. The construction materials for these structures can range from structural materials such as cast-in-place concrete or block to aggregate materials for construction of filters and drains. On-site borrow materials may be specified for backfill or for compacted fill as part of a barrier.

## 11.8 QUALITY CONTROL AND FIELD TESTING

Quality control and field testing are required for verification that a refuse facility is constructed according to plans, specifications and the operation and maintenance plan. The principal concerns for construction of a coal refuse disposal facility include:

- Compaction control where refuse is to be used as structural fill.
- Compaction control where borrow materials are to be used as structural fill.
- Verification that all areas that require structural fill are so constructed.
- Verification that material properties that affect construction operations, such as grain size, water content and compaction characteristics are in accordance with specifications.
- Verification that facility appurtenant structures, especially conduits and open channel spillways, are being constructed in accordance with design requirements, manufacturers' recommendations and good construction practice.

Activities that require quality control can be identified through review of the design report, plans, specifications, operation and maintenance plan for the facility, and technical chapters of this Manual, particularly Chapter 6.

### 11.8.1 Compaction Control

The monitoring of compaction in the field is essential for verification that structural fill refuse is compacted to a density meeting design requirements. The density of fill material should be tested in order to verify that the pertinent engineering properties of the fill that are a function of density, such as shear strength and hydraulic conductivity, are consistent with the values used in the design. Compaction control entails field testing during the construction of embankments and at other areas requiring structural fill refuse. Compaction test locations should be selected so as to include areas where routine compaction activities are performed, as well as areas that are more difficult for compaction equipment to access with repeated passes or where successful compaction is doubtful. At some sites, a grid system has been employed to aid in test location selection, and for each lift random grid points are chosen for testing. USBR publications (1987a, 1992a, 1998) discuss methods for testing compacted fill materials.

The in-situ density testing of structural fill has become much easier and more efficient with advances in nuclear testing methods. Unless special conditions arise during fill construction, most structural fill refuse, fine-grained soils, and fine gravels can be density tested using a nuclear density-moisture gauge. USACE (1995b) provides guidance on the use of these types of gauges, which should be operated in the direct transmission mode. Nuclear density-moisture gauges provide direct readings of in-situ density and the moisture content of fill. The instrument operates by projecting radiation (gamma rays) into the fill and measuring returns with a Geiger-Mueller detector. The instrument is easy to use and requires only observation of a digital read-out. However, the presence of varying amounts of hydrocarbons in coal refuse can cause the gauge to indicate higher than actual moisture contents.

Therefore, samples should be collected from the tested fill for laboratory moisture analysis so that accurate calculation of dry density can be performed.

For evaluation of the degree of compaction, measured field densities can be compared to Proctor density curves (Chapter 6) developed from laboratory testing. All field test results should be recorded. If test results indicate a lack of compliance with fill density requirements, compaction procedures should be modified. Areas of low density should receive additional compaction. If necessary, unacceptable fill should be removed and replaced, and recompaction should be performed. If it is determined that the fill is being compacted to densities greater than the maximum value from the Proctor test, an evaluation of the material (grain size and specific gravity) and the associated Proctor density curves may be necessary. In some cases, the presence of oversized particles, that is particles too large to be included in the Proctor mold (ASTM D 698), may be causing overestimation of density. If this is suspected, a sieve analysis should be performed and a rock-correction factor should be developed in accordance with ASTM D 4718, "Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles," and used to recalculate the maximum dry density of the refuse.

Application of the ASTM D 4718 may be difficult or precluded when coarse refuse contains more than 25 to 30 percent of plus-¾-inch particles, even after the oversize correction provisions using laboratory determined specific gravities are employed. Sometimes the oversize correction yields unreasonable target densities (usually higher than achievable), and in this case other compaction tests or field procedures should be considered. While determination of relative density in accordance with ASTM D 4253 and ASTM D 4254 is a possibility, this is generally not recommended because of the fine content in coal refuse. Another possible method for compaction control is the roller pass test (WVDOT, 1999). This method is discussed in Section 11.5.1.

Alternative material testing methods may be employed when more than 25 to 30 percent of plus-¾-inch particles are encountered. One such testing method is specified in Appendix VIA of the USACE Publication EM 1110-2-1906 titled, "Laboratory Soils Testing" (USACE, 1986). This method employs a 12-inch-diameter mold that accommodates larger particle sizes. Disadvantages to this method are that it is more costly than the ASTM D698 method, and many geotechnical laboratories are not equipped to perform the test. However, if refuse with a significant proportion of oversize particles is routinely generated, it may be effective to use the USACE test to supplement or replace the roller pass method.

In addition to periodic field density tests, visual observation of refuse placement and compaction should be performed regularly. If compacted material tests as having an "acceptable" density, but the surface is not firm, then the compaction specification should be re-evaluated. Regular observations by field personnel can often lead to acceptable modification of compaction procedures. Such observations are discussed in Section 11.6. Key observations for control of earth-fill operations are discussed by Church (1981) and USBR (1998). These observations, which typically apply to refuse disposal operations, include:

- Changes in lift thickness with subsequent passes of compaction equipment (including controlled routing of haul units) should be noted.
- Compaction equipment should not excessively "weave" or "rut" the fill. If this occurs, the material is too wet to be properly compacted.
- The compacted fill surface exhibits "pumping" under construction equipment traffic, which may indicate that lifts below the surface were compacted at too high a moisture content, and need to be uncovered and reworked.
- The feet of a sheepsfoot or tamper-type roller will first penetrate the loose material of a new lift, but should then begin to ride up on the material with each successive pass, as compaction is performed.

A consistent and reliable compaction procedure based upon a sufficient number of passes with appropriate equipment should be established. The USACE (1995b) provides general guidance relative to the number of passes required for various earthfill materials. Site-specific conditions must be considered in establishing compaction parameters.

It is recommended that structural fill refuse be compacted to at least 95 percent of the maximum dry density determined by the ASTM D 698. The refuse should be placed at a moisture content in the range indicated in the plans and specifications, typically in a range of −2 to +3 percent of optimum. The moisture content should be uniform throughout each lift. At least one field density test should be conducted for every 2,000 cubic yards of compacted structural fill with at least one test per lift. A common specification for compaction of pipe backfill and around structures is: at least one density test for every 200 cubic yards with at least one test per lift. Because of the importance of achieving adequate and consistent compaction of pipe backfill, more frequent density testing should be conducted. It is recommended that multiple tests be performed so that the testing frequency is significantly lower than every 200 cubic yards. Testing should also be performed whenever it is suspected that adequate compaction is not being achieved.

If failing density tests occur, it is the responsibility of field personnel to determine the cause of the failed tests. Generally, failed density tests are a result of either insufficient compaction or a change of material from that tested in accordance with ASTM D 698. If it suspected that the fill was not placed and compacted adequately, the limits of the lift and/or area should be marked, and mine personnel should be notified that the lift/area requires reworking and additional compaction. No additional refuse should be placed in the area with failed density tests until it has been adequately compacted. Additional density tests should be taken after the lift/area is reworked to verify the effectiveness of the additional compaction effort. If it is believed that the lift/area has been placed and compacted adequately, and a variation in grain-size distribution of the refuse being placed is suspected, a new sample should be collected for the ASTM D 698 testing. The Proctor curve(s) should be verified on a regular basis, typically between quarterly and annually.

### 11.8.2 Material Testing

The material properties of coal refuse, borrow materials, filter or drain gravels, and concrete can be determined by on-site field testing and/or by submittal of test samples to a qualified testing laboratory. Laboratories should be selected based on qualifications. The AASHTO Materials Reference Laboratory (AMRL) performs evaluation and accreditation programs for many construction materials, and the Geosynthetic Accreditation Institute – Laboratory Accreditation Program (GAI-LAP) performs similar evaluations for synthetic materials. Laboratories should be accredited through these programs for the type of testing being performed. Water contents and fill densities are best tested in the field for real-time assessment of compaction efficiency, but occasional test verification by an independent source may be appropriate. Strength testing of refuse, soils, concrete and other construction materials generally requires laboratory equipment and in some instances may be incorporated into quality control programs cited in the construction specifications.

Routine sampling and testing of construction materials is recommended during the development of a refuse disposal facility. The resulting records can be used for future evaluation of material performance and for submittals to regulatory agencies. Most importantly, material sampling and testing during construction increases confidence that the work is being performed in compliance with design requirements.