Designation: E2243 – 13

Standard Guide for
Use of Coal Combustion Products (CCPs) for Surface Mine Reclamation: Re-contouring and Highwall Reclamation[1]

1. Scope

1.1 This guide covers the use of coal combustion products (CCPs) for surface coal mine reclamation applications, as in beneficial use for reestablishing land contours, highwall reclamation, and other reclamation activities requiring fills or soil replacement. The purpose of this standard is to provide guidance on identification of CCPs with appropriate engineering and environmental performance appropriate for surface mine re-contouring and highwall reclamation applications. It does not apply to underground mine reclamation applications. There are many important differences in physical and chemical characteristics among the various types of CCPs available for use in mine reclamation. CCPs proposed for each project must be investigated thoroughly to design CCP placement activities to meet the project objectives. This guide provides procedures for consideration of engineering, economic, and environmental factors in the development of such applications, and should be used in conjunction with professional judgement. This guide is not intended to replace the standard of care by which the adequacy of a given professional service must be judged, nor should this guide be applied without consideration of a project's unique aspects.

1.2 The utilization of CCPs under this guide is a component of a pollution prevention program; Guide E1609 describes pollution prevention activities in more detail. Utilization of CCPs in this manner conserves land, natural resources, and energy.

1.3 This guide applies to CCPs produced primarily from the combustion of coal.

1.4 The testing, engineering, and construction practices for using CCPs in mine reclamation are similar to generally accepted practices for using other materials, including cement and soils, in mine reclamation. For guidance on structural fills to be constructed at mine sites, see applicable ASTM guide for coal ash structural fills.

1.5 Regulations governing the use of CCPs vary by state. The user of this standard guide has the responsibility to determine and comply with applicable regulations.

1.6 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C188 Test Method for Density of Hydraulic Cement
C311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
D75 Practice for Sampling Aggregates
D420 Guide to Site Characterization for Engineering Design and Construction Purposes (Withdrawn 2011)[3]
D422 Test Method for Particle-Size Analysis of Soils
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))
D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
D1195 Test Method for Repetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements
D1196 Test Method for Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for

[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.03 on Pollution Prevention/Beneficial Use.

Current edition approved Oct. 1, 2013. Published December 2013. Originally approved in 2002. Last previous edition approved in 2002 as E2243-02 which was withdrawn January 2011 and reinstated in October 2013. DOI: 10.1520/E2243-13.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

Use in Evaluation and Design of Airport and Highway Pavements
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1883 Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils
D2166 Test Method for Unconfined Compressive Strength of Cohesive Soil
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2435 Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
D3080 Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D3877 Test Methods for One-Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures
D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
D4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
D4429 Test Method for CBR (California Bearing Ratio) of Soils in Place
D4448 Guide for Sampling Ground-Water Monitoring Wells
D4767 Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils
D4972 Test Method for pH of Soils
D5084 Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
D5239 Practice for Characterizing Fly Ash for Use in Soil Stabilization
D5851 Guide for Planning and Implementing a Water Monitoring Program
E1609 Guide for Development and Implementation of a Pollution Prevention Program (Withdrawn 2010)[3]
E2201 Terminology for Coal Combustion Products

2.2 *AASHTO (American Association of State Highway and Transportation Officials) Standards:*[4]
T 288 Determining Minimum Laboratory Soil Resistivity
T 289 Determining pH of Soil for Use in Corrosion Testing
T 290 Determining Water Soluble Sulfate Ion Content in Soil
T 291 Determining Water Soluble Chloride Ion Content in Soil

2.3 *Other Methods*():
EPA Method 1312 Synthetic Precipitation Leaching Procedure (SPLP) **(1)**[5]
EPA Method 1320 Multiple Extraction Procedure (MEP) **(2)**
EPA Method Monofill Waste Extraction Procedure (MWEP) **(3)**
Synthetic Ground water Leaching Procedure (SGLP) **(4)**
Long-Term Leaching Procedure (LTL) **(4)**

3. Terminology

3.1 *Definitions*—For definitions related to coal combustion products, see Terminology E2201. For definitions related to geotechnical properties, see Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *internal erosion*—piping; the progressive removal of soil particles from a mass by percolating water, leading to the development of channels.

3.2.2 *permeability*—the capacity to conduct liquid or gas. It is measured as the proportionality constant, k, between flow velocity, v, and hydraulic gradient, i; $v = ki$.

4. Background

4.1 *Significance and Use*—CCPs can be effective materials for use for reclamation of surface mines. Following are key scenarios in which CCPs may be utilized beneficially in a mined setting:

Structural fill
Road construction
Soil modification or amendment for revegetation **(5-9)**
Isolation of acid forming materials **(5)**
Reduction of acid mine drainage (AMD) **(5,10-15)**
Highwall mining **(16,17)**

4.1.1 These options represent most, but not all, scenarios under which CCPs would be returned to the mine. This guide discusses issues related to highwall mining and recontouring. Because of the chemical and physical characteristics of CCPs and the benefits derived from the use of CCPs in these applications, placement of CCPs in a surface mine setting qualifies as a beneficial use as defined in Terminology E2201.

4.1.2 CCPs are ideally suited for use in numerous fill applications. Structural fills and other high-volume fills are significant opportunities for placement of CCPs in mine situations for reclamation, recontouring, and stabilizing slopes. These applications are the focus of this guide.

4.1.3 Any type of CCP may be evaluated for use in mine reclamation, even fly ash with high carbon content. Project-specific testing is necessary to ensure that the CCPs selected for use on a given project will meet the project objectives. The use of CCPs can be cost effective because they are available in bulk quantities and reduce expenditures for the manufacture and purchase of borrow material, Portland cement, or quicklime. Large-scale use of CCPs for mine reclamation conserves landfill space by recycling a valuable product, provided that the CCP is environmentally and technically suitable for the desired use.

[4] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

[5] The boldface numbers in parentheses refer to the list of references at the end of this guide.

4.2 *Use of CCPs for Mine Reclamation*—E2201 the Standard on Fly ash, bottom ash, boiler slag, FGD material, and FBC ash or combinations thereof can be used for mine reclamation. Each of these materials typically exhibits general physical and chemical properties that must be considered in the design of a mine reclamation project using CCPs. The specific properties of these materials vary from source to source, so environmental and engineering performance testing is recommended for the material(s) or combinations to be used in mine reclamation projects. Guidance in evaluating the physical, engineering, and chemical properties of CCPs is given in Sections 6 and 7.

4.3 *Engineering Properties and Behavior*—Depending on the mine reclamation application, fly ash, bottom ash, boiler slag, FGD material, FBC fly ash, FBC bottom ash, or combinations thereof may have suitable and/or advantageous properties. Each of these materials typically exhibits general engineering properties that must be considered in engineering applications. These general engineering properties are discussed in the following subsections; however, it should be noted that the specific engineering properties of these materials can vary greatly from source to source and must be evaluated for each material, or combination of materials, to be utilized for a structural fill.

4.3.1 *Unit Weight*—Many CCPs have relatively low unit weights. This is sometimes referred to as "bulk density" in the literature. The low unit weight of these materials can be advantageous for some structural fill applications. The lighter-weight material will reduce the load on weak layers or zones of soft foundation soils such as poorly consolidated or landslide-prone soils. Additionally, the low unit weight of these materials may reduce transportation costs, since less tonnage of material is hauled to fill a given volume. Lower density fills of equal internal angle of friction will exert less lateral pressure on retaining structures.

4.3.1.1 Fly ash is typically lighter than the fill soil it replaces, with unit weight ranging from about 50 to 100 pcf (8 to 16 kN/m^3).

4.3.1.2 Bottom ash is also typically less dense than coarse-grained soils of similar gradation, with unit weight ranging from about 70 to 90 pcf (11 to 14 kN/m^3).

4.3.1.3 Boiler slag is typically as heavy as, if not heavier than, natural soils of similar gradation, with unit weight ranging from about 90 to 110 pcf (14 to 18 kN/m^3).

4.3.1.4 Oxidized and/or fixated FGD materials are also relatively lightweight, with unit weights ranging from about 50 to 100 pcf (8 to 16 kN/m^3).

4.3.2 *Compaction Characteristics*—Most CCPs can be placed and compacted in a manner very similar to soil and aggregate fill materials. In fact, most CCPs exhibit very little cohesion and are not as sensitive to variations in moisture content as are natural soils.

4.3.2.1 Fly ash, FGD material, and FBC ash are typically placed and compacted in a manner similar to noncohesive fine-grained soils. Smooth-drum vibratory rollers or pneumatic tired rollers typically compact these materials most effectively. Although not always, fly ash and FGD material typically exhibit a measurable moisture-density relationship that can be utilized for compaction quality control. To take full advantage of the self-hardening properties of some fly ash, FGD material, and FBC ash, compaction soon after the addition of water is recommended. If hardening or cementation has occurred prior to compaction, cementitious bonds may need to be disrupted to relocate the grains into a more dense state (**18**). Strength and permeability will not be the same for self-hardening materials compacted before cementation has occurred as for those compacted after cementation has occurred. Compaction criteria are usually not specified for FGD material that exhibits thixotropic properties.

4.3.2.2 Bottom ash is generally placed and compacted in a manner similar to noncohesive coarse-grained soils or fine aggregate. Smooth-drum vibratory rollers typically are most effective for the compaction of these materials. Bottom ash may or may not exhibit consistent moisture-density relationships. Bottom ash typically compacts best when saturated. Bottom ash should be compacted to a specified density.

4.3.2.3 Boiler slag is generally placed and compacted in a manner similar to noncohesive coarse-grained soils or fine aggregate. Smooth-drum vibratory rollers typically are most effective for the compaction of these materials. As with bottom ash, boiler slag may or may not exhibit consistent moisture-density relationships. Boiler slag typically compacts best when saturated.

4.3.3 *Strength:*

4.3.3.1 *Shear Strength*—For non-self-hardening fly ash and bottom ash, shear strength is derived primarily from internal friction. Typical values for angles of internal friction for non-self-hardening fly ash are higher than those for many natural soils. These ashes are non-cohesive, and although the ash may appear cohesive in a partially saturated state, this effect is lost when the material is either completely dried or saturated.

(1) Because of its angular shape, the shear strength of bottom ash is typically greater than that of fly ash and is similar to the shear strength of natural materials of similar gradation. However, friable bottom ash may exhibit lower shear strength than natural materials of similar gradation.

(2) The shear strength of boiler slag may be higher than that of natural materials of similar gradation, owing in part to the typically angular shape and hardness of the particles.

4.3.3.2 *Compressive Strength*—Self-hardening CCPs and stabilized FGD material undergo a cementing process that increases with time. Hydration of dry self-hardening CCPs commences immediately upon exposure to water and can cement the CCP particles in a loose state, reducing the compacted density and strength. High compressive strengths can be achieved if the CCPs are compacted immediately after incorporation of water. Unconfined compressive strengths greater than 2000 psi have been reported for a cementitious ash-water mixture after 248 days (**18**).

4.3.4 *Consolidation Characteristics*—Structural fills constructed of fly ash or FGD material typically exhibit small amounts of time-dependent, postconstruction consolidation. This is because excess pore water pressures dissipate relatively rapidly, and thus most of the embankment settlement or deformation occurs as a result of elastic deformation of the material rather than by classical consolidation. Most deformation due to the mass of the fill or structure thereof generally occurs during construction.

4.3.4.1 Bottom ash and boiler slag are free-draining materials that can be compacted into a relatively dense, incompressible mass. For this reason, structural fills constructed of bottom ash or boiler slag also typically exhibit small amounts of time-dependent, postconstruction consolidation or deformation, with the most deformation occurring during construction.

4.3.4.2 Self-hardening fly ash and FGD material typically exhibit minimal postconstruction consolidation or deformation because of cementing and solidification of the CCPs.

4.3.5 *Permeability*—The values for permeability of CCPs range greatly depending on the type of CCP, the degree of compaction, and other placement variables.

4.3.5.1 The permeability values for non-self-hardening fly ash are similar to those observed for natural silty soils.

4.3.5.2 Self-hardening fly ash and FGD material are relatively impermeable, with permeability values similar to those for natural clays. Self-hardening fly ash and some FGD material may be susceptible to cracking in the environment. Cracking can produce a conduit for liquids through the placed material and change the measured permeability.

4.3.5.3 Bottom ash and boiler slag are typically as permeable as granular soils of similar gradation.

4.3.6 *Erosion Characteristics:*

4.3.6.1 *Internal Erosion (Piping)*—Non-self-hardening fly ash is subject to internal erosion because of its fine-grained, noncohesive nature. Internal erosion can be controlled by providing adequate surface water controls to minimize infiltration and by providing internal drainage when warranted.

(1) Bottom ash and boiler slag typically are well graded and capable of being compacted to a stable mass. These attributes usually preclude any problems arising from internal piping of material.

(2) Self-hardening fly ash and FGD material are usually not subject to internal erosion.

4.3.6.2 *Surface Erosion*—All CCPs may be eroded by wind or water and require use of erosion controls similar to those commonly used on earthwork construction projects. Wind erosion may be controlled by use of wind breaks. Dusting may be controlled by addition of water, or conditioning, to non-self-hardening materials. Water erosion can be limited by controlling water at the site by using sedimentation, sloping, and run-off controls meeting regulatory requirements. These controls should be put in place under the supervision of a qualified professional.

4.3.7 *Swelling*—Some self-hardening CCPs may swell with time. Paragraph 6.3.8 provides guidance on evaluating the swelling potential of CCPs.

4.3.8 *Liquefaction and Frost Heave*—Although fine-grained and noncohesive materials such as fly ash are susceptible to liquefaction and frost heave when saturated, these problems are readily controlled by design practices that allow for drainage away from the ash fill. Because of fly ash sensitivity to moisture, it is standard practice to design fills to be well drained. Typically, drainage blankets to provide internal drainage and serve as a capillary barrier are included at the base of fills. Also, locating fills in areas where they are not subject to saturation or infiltration by surface water or ground water is normally considered in design. Self-hardening and stabilized fly ash and FGD material are not susceptible to liquefaction. Non-stabilized wet FGD material is highly susceptible to frost heave.

4.3.8.1 Well-compacted bottom ash and boiler slag are not typically susceptible to either liquefaction or frost heave. However, some of the finer bottom ash materials may behave quite similarly to fly ash and would require the same consideration for design as fly ash embankments.

4.3.9 *Specific Gravity*—Specific gravity is the ratio of the weight in air of a given volume of solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature. The particle specific gravity of fly ash is relatively low compared to that of natural materials and generally ranges from 2.1 to 2.6 (**19**).

4.3.10 *Grain-Size Distribution*—Grain-size distribution describes the proportion of various particle sizes present in a material. Fly ash is a uniformly graded product with spherical, very fine-grained particles.

4.3.11 *Moisture Content*—Moisture content is the ratio of the mass of water contained in the pore spaces of soil or rock material to the solid mass of particles in that material, expressed as a percentage. Most CCPs have almost no moisture when first collected after the combustion of coal. Nonstabilized wet FGD material has a high moisture content. Power plant operators sometimes add moisture to facilitate transport and handling, a process termed conditioning.

4.3.12 *Thixotropy*—The property of some gels to become fluids when disturbed by energy events such as vibration. This property may be exhibited by some FGD materials.

4.4 *Chemical Properties:*

4.4.1 *Elemental Composition*—The major elemental components of CCPs are silicon, aluminum, iron, calcium, magnesium, sodium, potassium, and sulfur. These elements are present in various amounts and combinations dependent primarily on the coal type (bituminous, subbituminous, or lignite) and type of CCP (coal fly ash, FBC fly ash, FGD material, and so forth). Trace constituents may include trace elements such as arsenic, boron, cadmium, chromium, copper, chlorine, mercury, manganese, molybdenum, selenium, or zinc (**20**).

4.4.2 *Phase Associations*—The primary elemental constituents of CCPs are present either as amorphous (glassy) phases or crystalline phases. Coal combustion fly ash is typically 70+ % amorphous material. FGD and FBC products are primarily crystalline, and the crystalline phases typically include calcium-based minerals.

4.4.3 *Pozzolanic Activity*—Most fly ash is characterized as pozzolanic because of the presence of siliceous or siliceous and aluminous materials that in themselves possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

4.4.4 *Hygroscopy*—Most CCPs are captured and then handled in conditions that either create or preserve dehydrated conditions. Some CCPs have distinctive stable states of hydration. This stable hydration state needs to be considered in some applications of CCPs.

4.5 *Environmental Considerations:*

4.5.1 *Regulatory Framework:*

4.5.1.1 *Federal*—The U.S. Department of the Interior Office of Surface Mining (OSM) is charged with the responsibility of ensuring that the national requirements for protecting the environment during coal mining are met and making sure the land is reclaimed after it is mined. When the use of CCPs occurs at surface coal mines, state or federal coal-mining regulators are involved to the extent that SMCRA (Surface Mining Control and Reclamation Act) requires the mine operator to ensure that:

(1) All toxic materials are treated, buried, and compacted, or otherwise disposed of, in a manner designed to prevent contamination of ground or surface water (30 CFR 816/817.41).

(2) The proposed land use does not present any actual or probable threat of water pollution (30 CFR 816/817.133).

(3) The permit application contains a detailed description of the measures to be taken during mining and reclamation to assure the protection of the quality and quantity of surface and ground water systems, both on- and off-site, from adverse effects of the mining and reclamation process (30 CFR 780.21).

(4) The rights of present users of such water are protected (30 CFR 816/817.41).

(5) Any disposal of CCPs at mine sites must be in accordance with those standards and with applicable solid waste disposal requirements (30 CFR 816/817.89).

(a) SMCRA gives primary responsibility for regulating surface coal mine reclamation to the states, and 24 coal-producing states have chosen to exercise that responsibility. On federal lands and Indian reservations (Navajo, Hopi, and Crow) and in the coal states that have not set up their own regulatory programs (Tennessee and Washington), OSM issues the coal mine permits, conducts the inspections, and handles the enforcement responsibilities. As a result of the activities associated with the SMCRA, coal mine operators now reclaim as they mine, and mined lands are no longer abandoned without proper reclamation. OSM also collects and distributes funds from a tax on coal production to reclaim mined lands that were abandoned without being reclaimed before 1977. OSM has a Coal Combustion Residues Management Program that focuses on providing expert technical information on the use of CCPs in mine reclamation for the mining industry, regulatory agencies, and other stakeholders.

(b) In 1999, U.S. Environmental Protection Agency (EPA) completed a two-phased study of CCPs for the U.S. Congress as required by the Bevill Amendment to RCRA. At the conclusion of the first phase in 1993, EPA issued a formal regulatory determination that the characteristics and management of the four large-volume fossil fuel combustion waste streams (that is, fly ash, bottom ash, boiler slag, and flue gas emission control waste) do not warrant hazardous waste regulation under RCRA and that utilization practices for CCPs appear to be safe. In addition, EPA "encourage[d] the utilization of coal combustion byproducts and support[ed] State efforts to promote utilization in an environmentally beneficial manner." In the second phase of the study, EPA focused on the byproducts generated from FBC boiler units and the use of CCPs from FBC and conventional boiler units for mine reclamation, among other things. Following completion of the study, EPA issued a regulatory determination that again concluded that hazardous waste regulation of these combustion residues was not warranted. However, EPA also decided to develop national solid waste regulatory standards for CCPs, including standards for placement of CCPs in surface or underground mines, either under RCRA, SMCRA, or a combination of the two programs (65 CFR 32214, May 22, 2000).

4.5.1.2 *State and Local*—There is considerable variation in state-mandated permitting and other regulatory requirements for CCP utilization. Some states have specific beneficial use policies, while other states have no regulations or guidance addressing beneficial use. Although the NEPA (National Environmental Policy Act) strictly applies only to federally funded projects, many states have similar mechanisms for assessing the environmental impacts of non-Federal projects. These mechanisms may require state permits that address any or all of the following issues: wetlands/waterways, National Pollutant Discharge Elimination System (NPDES) discharge, underground injection, erosion and sediment control, air quality considerations, and storm water management.

4.5.2 *Water Quality*—When planning to use CCPs for mine reclamation, one should consider the potential impacts on ground water and surface water to ensure protection of human health and the environment.

4.5.2.1 *Ground Water*—The design and implementation of a mine reclamation project should consider the potential ground water impacts of CCPs to ensure the protection of human health and the environment. Considerable research has been conducted to assess and predict the potential impacts of CCP utilization on ground water quality. An assessment of ground water quality impacts should be performed by a qualified professional and should take into account project-specific considerations such as composition of CCPs, the typically limited leachability of CCPs, presence of acid forming materials or acid mine drainage, placement of CCPs relative to the ground water table, rates of infiltration, the type of placement used for the CCP, and constituent migration, attenuation in ground water, and location of sensitive receptors (that is, wells). Where protection of ground water is a special concern, the leaching characteristics of the CCP should be evaluated as part of the assessment of constituent migration and attenuation. Consideration should be given to the leachability of the CCP in the presence of AMD. Some states may require a groundwater protection plan be prepared outlining controls that will limit potential impact to groundwater.

4.5.2.2 *Surface Water*—CCPs may affect surface water bodies during and after placement activities as a result of erosion and sediment transport. The engineering and construction practices recommended to minimize these effects on surface waters include storing the CCPs in stockpiles employing effective storm water management controls to maximize runoff and minimize run-on.

4.5.3 *Air Quality*—When planning to use CCPs for mine reclamation, one should consider the potential impacts to air quality including dusting.

4.5.3.1 *Dust Control*—Dusting must be controlled during the transport and handling of CCPs in order to avoid fugitive dust and to ensure worker safety. Dust control measures routinely used on earthwork projects are effective in minimizing airborne particulates at CCP storage sites. Typical controls include appropriate hauling methods, use of windbreaks, moisture conditioning of the CCPs, storage in bins or silos, covering the CCPs with large tarpaulins, wetting or covering exposed CCP surfaces, and paving or wetting unpaved high-traffic haul roads with coarse materials.

4.5.3.2 *Radionuclides*—Coal and fly ash are not significantly enriched in radioactive elements or in associated radioactivity compared to common soils or rocks (**21**). Certain radioactive elements including radium and uranium are known to occur naturally in CCPs (**15**) and other fill materials. The U.S. Department of Energy estimated the radium concentration of fly ash to be no more than 3.0 pCi/g (**22**). Radon emissions from the CCPs are not likely to exceed the naturally occurring ambient emissions.

4.6 *Economic Benefits*—The use of CCPs for mine reclamation can have economic benefits. These benefits are affected by local and regional factors, including production rates, processing and handling costs, transportation costs, availability and cost of competing materials, environmental concerns, and the experience of materials specifiers, design engineers, purchasing agents, contractors, legislators, regulators, and other professionals. CCPs are competing as manufactured materials and not as waste products, however in the event that CCPs do not meet beneficial use requirements or cannot be utilized, they should be managed at an appropriate waste facility. Since CCPs are produced in the process of manufacturing electricity, these materials can present an advantage when utilized as raw products for finished goods. This is primarily due to the low overheads involved with the material production cost and the fact that some, but not all coal-fired power plants have immediate access to low-cost transportation. The transport of coal to the power plant can provide an excellent opportunity to return CCPs to a mine site to aid in mine reclamation projects.

5. Site Characterization

5.1 *General*—The siting and design of a mine reclamation project requires the identification and resolution of site access and environmental issues and completion of a geologic and hydrogeologic investigation to characterize the subsurface and mine conditions. The degree to which these activities are needed to support the engineering design will vary for each mine site, depending upon whether the sites are abandoned or active. In the case of surface coal mines, contemporaneous reclamation is required under the Surface Mining Law, and the reclamation plan is a required part of the permit granted either by the state or OSM.

5.2 *Geologic and Hydrogeologic Investigation*—The site conditions must be understood. This typically involves a review of mine maps and other available information to aid in understanding the site hydraulic conductivity, ground water flow and recharge, water table, and other pertinent information as determined by a qualified professional.

5.3 *Environmental Resources*—The water supply must be considered in evaluating environmental resources at a specific site. Additionally, many sensitive environmental resources such as wetlands, flood plains, surface water bodies, rare and endangered species, and cultural resource areas are afforded protection by federal, state, and local regulations and ordinances. Appropriate action should be taken to comply with the requirements of the regulatory agencies having jurisdiction at the mine site.

5.4 *Mine Characterization*—Two key components of site characterization for mine reclamation applications are (*1*) identification of the mine configuration and geometry and (*2*) evaluation of mine hydrology.

5.4.1 *Mine Configuration*—Typical surface-mining methods include area mining, contour mining, and mountaintop removal mining. Each of these methods requires specific types of reclamation activities.

5.4.1.1 Area mining is commonly used in flat or moderately rolling terrain. The overburden is excavated, and the mine is expanded horizontally. Topsoil and overburden need to be replaced as the mined area expands. CCPs can be used to augment overburden and/or topsoil.

5.4.1.2 Contour mining is typically used in mountainous terrain. A cut is made into the side of the hill or mountain, and the mine is expanded by further cuts into the mountain and around the perimeter of the mountain. Highwall areas result from the cuts into the mountain, and these are good candidate areas for reclaiming with CCPs. CCPs can also be used in stabilizing the slope of the reclaimed contour mine and in the preparation of the surface for ground cover required to minimize erosion.

5.4.1.3 Mountaintop removal mining is similar to area mining, except that the entire top of a mountain is mined. Topsoil and overburden need to be replaced as the mined area expands. CCPs can be used to augment overburden and/or topsoil.

5.4.2 *Mine Hydrology*—The hydrology of the mine must be understood so that reclamation can be optimized and water quantity and quality protected. The techniques used to characterize mine hydrology are similar to those for a geologic and hydrogeologic investigation.

5.5 *Environmental Monitoring*—Environmental monitoring provides a means of documenting whether the CCPs used in reclamation activities have impacted the site or surrounding area. Baseline monitoring should be conducted during site characterization activities and should include the parameters (metals and non-metals) attributable to CCPs. At a minimum, the monitoring should include the collection of precipitation quantity, mine drainage and surrounding surface water quality and quantity, and ground water elevation and quality. Guides D5851 and D4448 discuss sampling techniques. All water quality samples should be submitted for laboratory analysis of those chemical parameters deemed appropriate to characterize the baseline water quality of the mine and surrounding site. Monitoring should be conducted at the appropriate frequency to ensure that any seasonal variations in water quality and flow are characterized. Both the chemical parameters and the sampling frequency should be in accordance with requirements of appropriate governing agencies.

6. Laboratory Test Procedures

6.1 *General*—Laboratory testing of the proposed CCPs is needed to determine and confirm material properties for design. Test results also provide documentation that may be requested or required by site owners and regulatory agencies. The tests to be conducted should be determined on the basis of site conditions, knowledge of the CCPs, end use, and local environmental considerations.

6.2 *Sampling and Handling*—Sampling CCPs for testing purposes should conform to Practice D75 or Test Methods C311, as appropriate. Guide D420 with sample extraction conducted in accordance with Practice D1452, Test Method D1586, or Practice D3550, as appropriate, should be considered. Proper laboratory protocols for handling fine-grained material should be followed.

6.3 *Physical and Engineering Characteristics*—Several standard test methods developed for soils may be used to determine CCP properties for use in surface mine applications. These test methods define physical and engineering parameters for use in design and construction control and for comparison to other materials. Because of the noncohesive nature of some CCPs, extra care in sample handling may be required. These tests and/or other tests may be warranted depending on the specific mine application for CCPs and should be selected based on the professional judgement of a qualified scientist or engineer.

6.3.1 *Grain-Size Distribution*—Test Method D422 is commonly used for determining the grain-size distribution of CCPs. For fly ash and FGD material, a substantial portion of the material will be finer than the No. 200 sieve, and hydrometer analyses will also be required. Distilled water is used in the hydrometer test, with a deflocculating agent added to prevent fly ash or FGD material from forming flocs. Self-hardening fly ash(es) and FGD material may require use of alcohol or another nonreactive solution in place of the standard solution. Fly ash often has a relatively uniform particle size, and precautions against overloading sieves are warranted. Specimen loss through dusting can also be a problem. Specific gravity may vary with particle size. Specific gravity values used in hydrometer analyses should be appropriate to the portion of the sample being tested. Test Method D422 is not applicable to fly ash with a specific gravity less than 1 unless a nonaqueous solvent is used. Grain-size or particle size distribution may also be determined by use of dry powder laser diffraction, retention of particles on sieves, or optical particle counters.

6.3.2 *Specific Gravity*—Test Method D854 is normally used for CCPs. For some fly ash and FGD samples, a significant portion of the particles may have a density less than water, and these will float. Agitation of the slurry may be needed to keep the particles in suspension so that the average specific gravity can be obtained. Alternately for this ash, self-hardening fly ash, and FGD material, Test Method C188, which uses kerosene as the fluid, may be used.

6.3.3 *Water Content*—Test Method D2216 is normally used for CCPs. For self-hardening fly ash and FGD material, lowering the drying temperature to 140°F (60°C) may be considered to avoid driving off the water of hydration.

6.3.4 *Compaction:*

6.3.4.1 *Fly Ash and FGD Material*—Test Methods D698 or D1557 may be used, depending on end use. For dry self-hardening fly ash and FGD material, the time interval between wetting and compaction in the laboratory should be similar to that anticipated during construction to account for the influence of the rate of hydration on compaction characteristics. Compaction criteria are not typically developed for FGD material that exhibits thixotropic properties, because excessive compaction may cause the material to liquefy.

6.3.4.2 *Bottom Ash and Boiler Slag*—Test Methods D4253 and D4254 may be used for the determination of maximum and minimum density of coarse-grained CCPs that do not exhibit a moisture-density relationship.

6.3.5 *Strength*—Material strength is defined by shear strength and compressive strength.

6.3.5.1 *Shear Strength*—Test Method D3080 can be used to determine the shear strength parameters of compacted CCP specimens under drained conditions. This test is preferred because it models the drained conditions that typically exist in a structural fill constructed of CCPs. When Test Method D3080 is used, the method is modified in that the shear box is not to be filled with water as required by Test Method D3080.

6.3.5.2 *Compressive Strength of Non-Self-Hardening CCPs*—Test Method D4767 can be used to predict the as-constructed compressive strength of the CCP fill and to design for specific site conditions, loading conditions, and final height. Specimens tested for strength parameters shall be compacted to the densities and water contents required by the project compaction specifications.

6.3.5.3 *Compressive Strength of Self-Hardening Fly Ash and FGD Material*—Test Method D2166 can be used to determine the unconfined compressive strength at various ages to evaluate short-term and long-term strength development.

6.3.6 *Hydraulic Conductivity*—Test Method D5084 is commonly used to determine the hydraulic conductivity of saturated CCPs.

6.3.7 *Compressibility*—Samples should be prepared at the degree of compaction specified for construction and at the optimum water content determined by the compaction test. This is because fly ash and FGD material tend to lose surface stability in the field when compacted at water contents greater than the optimum for compaction. Special considerations may be required for wet FGD material which is typically produced at 15 to 20 % above optimum moisture. Test Method D2435 can be used to determine the compressibility of saturated or unsaturated samples.

6.3.8 *Swelling*—Test Method D3877 can be used to determine the swelling potential of self-hardening fly ash and FGD material. Reactions producing the expansive properties do not commence for a period of more than 30 days after initial ash hydration. The test procedures must address this delayed reaction. The procedure should be modified to extend the wetting and drying cycles to a frequency determined by a qualified design engineer.

6.4 *Chemical Characteristics*—Chemical analyses are routinely conducted by many CCP producers as a means of determining material variation. The mine reclamation designer(s) and other professionals should obtain or evaluate the chemical characteristics of candidate CCPs so they can be considered in design, particularly with regard to assessing chemical interaction between fill and other materials or structures. Tests for soluble species, generally accomplished through leaching tests, may also be required by local regulatory agencies.

6.4.1 *Chemical Composition*—Test Method C311 is often used to determine the major chemical constituents of CCP samples.

6.4.2 *pH*—Test Method D4972 or Practice D5239 may be used to determine CCP pH. In assessing the test results, consideration should be given to the possibility that the pH of the CCP may vary with age, water content, and other conditions.

6.4.3 *Sulfate*—Sulfate content as determined from the CCP chemical analysis by Test Method C311 or other method is used in a preliminary assessment of the potential for sulfate attack on concrete. As with corrosivity, likely field water conditions and variations in concentrations with time should be considered.

6.4.4 *Leaching Characterization*—Numerous leaching tests have been developed to evaluate the leaching behavior of materials. Commonly applied leaching tests are listed and referenced in Table 1, but the selection of the test procedure(s), leachate test parameters, and interpretation of leachate test results must be guided by professional judgement and the appropriate regulatory authority.

TABLE 1 Leaching Methods Applicable to Stabilized Materials

	Leaching Solution	Liquid: Solid Ratio	Leaching Duration
MEP (2)	Multiple solutions (acetic acid, sulfuric acid, and nitric acid)	20:1	24 h/ extraction
MWEP (3)	Distilled/ deionized water or other for specific silt	10:1	18 h/ extraction
ASTM D3987	Distilled/ deionized water	20:1	24 h
SGLP (4)/ LTL (4)	Synthetic ground water dictated by site or distilled/ deionized water	20:1	18 h/ 30, 60, 90 days
SPLP (1)	Sulfuric acid	20:1	18 h

7. Design Considerations

7.1 *General*—Design involves developing a plan that integrates the mine-specific design requirements with the physical and engineering properties of the CCP. In addition, the design must address the objectives of the mine reclamation (for example, abatement of AMD, recontouring, stabilizing highwalls or fills, a topsoil substitute or amendment for reestablishing vegetation).

7.2 *Design Process*—The design process is an iterative procedure whereby information concerning site and material constraints are balanced against project goals. Information is developed in increasing detail and analyzed to evaluate whether the site development plan is satisfactory. Adjustments to the development plan or material properties are made to accomplish the project goals.

7.2.1 *Conceptual Site Model*—Initially, a conceptual site model should be developed that identifies specific characteristics with regard to the geology, hydrogeology, and topography of the project site, as well as the configuration and discharge characteristics of the mine. Pertinent CCP characteristics such as density, pozzolanic or cementitious activity, buffering capacity, and permeability should be determined for design use. The model should address the changes in CCP properties that may occur over time, such as strength gain or loss. Site and CCP characteristics may be determined by experience, literature searches, site reconnaissance, laboratory testing, or field testing and sampling or some combination thereof.

7.2.2 *Conceptual Design*—Conceptual design involves preparing a plan for site development that meets project goals within the constraints of site and material characteristics and project budget. A general assessment of project feasibility is normally conducted as part of the conceptual design.

7.2.3 *Detailed Design*—The detailed design involves such components as surface water drainage for erosion control, planning of site preparation and water management activities, and selection of placement techniques and equipment.

7.2.4 *Other Design Considerations*—Consideration must be given to potential water and air quality impacts in accordance with 4.5.1, 4.5.2, and 4.5.3, respectively. It is also appropriate to resolve any questions and approvals needed from local, state, or federal agencies.

7.3 *Site Preparation*—Site preparation will vary between active mine sites undergoing contemporaneous reclamation and abandoned mined lands requiring reclamation. Site preparation may include diversion and control of surface drainage, installation of controls for erosion and sedimentation, draining and/or drying wet areas, removal of unsuitable materials at the site such as vegetation and topsoil, providing areas to stockpile any soil needed in the reclamation process, and development of access roads for placement of the CCPs.

7.3.1 *Access Roads*—Access roads should be available to accommodate the flow of traffic to the project site. New access roads may need to be installed where there is none, or existing access roads can be improved. The roads should be accessible to trucks and equipment needed to place CCPs. The roads should be designed to safely handle a certain number of trucks on a daily basis, depending upon the size of the mine reclamation project. Finally, road maintenance may be required during the course of the project to ensure safe access to the site.

7.3.2 *CCP Delivery and Stockpiling:*

7.3.2.1 *Delivery*—The number and volume of CCP deliveries needed on a daily basis depend upon the CCP placement technique and application(s) and the size of the mine reclamation project. The project should ensure that appropriate delivery schedules are identified and met on the basis of these requirements. In addition, traffic routing and control measures may be necessary to facilitate large numbers of delivery trucks, especially in active mines.

7.3.2.2 *Stockpiling*—Material stockpiles should be constructed and maintained for each of the CCPs. The material stockpiles may consist of open-air bins, piles or, in the event that moisture-sensitive CCPs are used, closed silos. The final configuration of the stockpiling area should incorporate dust control measures, minimize soil disturbance to the greatest extent practicable, and control runoff to reduce storm water impacts. CCPs to be used in mine reclamation activities may also be recovered from disposal facilities which may preclude the need for stockpiling.

7.3.3 *Erosion and Sediment Control*—An erosion and sediment control plan (ESCP) must be prepared, approved, and implemented prior to the initiation of CCP placement activities. The ESCP must conform to state standards and specifications. ESCP control measures must be maintained for the duration of the project. The ESCP is generally part of the mining permit for surface mines which is obtained from the appropriate state agency or the Office of Surface Mining.

7.4 *Surface Cover and Drainage*—Provisions must be made for controlling erosion of CCPs. Because of its fine-grained, noncohesive nature, non-self-hardening fly ash is readily eroded. Unprotected, compacted CCPs are erodible when exposed to surface runoff or high winds. Erosion control is normally accomplished by controlling surface drainage and establishing permanent cover with pavement or soil and vegetation.

7.4.1 *Cover*—Effective cover to control erosion can be either pavement or soil, depending upon the final use of the surface. Surface configuration should include provisions for controlled, positive drainage of surface runoff. Minimum slopes to prevent ponding both on surfaces and in drainage ways of approximately 1 to 3 % are desirable so that settlement and minor surface variations can be accommodated.

7.4.2 *Surface Drainage*—Positive surface drainage is needed to prevent ponding that can lead to erosion problems. Suitable channel linings designed to accommodate storm flows without damage are needed. Slopes on surface areas and in drainage channels should be sufficient to prevent ponding and avoid long-term maintenance problems.

7.5 *Structural Performance*—In any fill application, CCPs and other fill material must support their own mass, support loads to be placed on them, and have acceptable settlement. Each of these aspects is analyzed as part of the design process.

7.5.1 *Slope Stability*—Embankment slopes should be stable and able to stand without slumping or sliding. Stability analyses should consider static, dynamic, and seismic loadings and seepage forces, as appropriate. Desired factors of safety typically range from 1.2 (seismic and dynamic) to 1.5 (static). Stability of exterior slopes, foundation soils, embankments, and cover soils should be analyzed.

7.5.2 *Settlement*—As with any fill material, settlement due to consolidation and compression of the fill and the underlying materials should be considered in design. Settlement may adversely affect project performance if not taken into consideration. Settlement magnitude and duration are commonly compensated for in the design process without difficulty.

7.6 *Compaction*—Proper and uniform compaction (including control of molding water content) of CCPs placed in a fill increases the strength of the material, reduces the compressibility, and produces a relatively uniform fill. The CCPs are readily spread and compacted by conventional construction equipment. Self-cementing CCPs may react and set up, which may preclude the use of field compaction tests to evaluate field compaction.

7.6.1 *Fly Ash and Nonthixotropic FGD Material*—Because they are fine-grained, fly ash and nonthixotropic FGD materials exhibit compaction behavior under static compaction similar to that of natural soils in that compaction is sensitive to molding water content. Most fly ash and nonthixotropic FGD materials have well-defined compaction relationships; that is, for a given static compactive energy, there exists an optimum water content at which compaction of the CCP will achieve the maximum dry density. Attempting to compact fly ash or FGD material above the optimum water content results in displacement of the fly ash or FGD material, and limited densification is attained. Static compaction of fly ash or FGD material having a water content below the optimum requires more compactive effort to achieve desired results. However, the compaction of fly ash is not especially sensitive to variations in water content when vibratory compactors operated at the resonant frequency are used. Thus fly ash that is several percentages below the optimum water content can be readily compacted in this way. Compaction characteristics of dry self-hardening ash or FGD material change rapidly with time after exposure to water. This property is a result of the rapid rate of hydration that produces a cementitious reaction. A reduction in maximum density of more than 30 lb/ft^3 can occur and must be addressed by the design and compaction procedures.

7.6.2 *Thixotropic FGD Material*—It is not appropriate to specify compaction criteria for thixotropic FGD material, because excess water is present making it a non-compressible material which cannot be compacted.

7.6.3 *Bottom Ash and Boiler Slag*—These CCPs are typically free-draining; therefore, unless they are saturated, the moisture content of these materials has little influence on their compaction characteristics. Simply wetting the bottom ash or slag sufficiently to prevent bulking will promote adequate compaction.

7.6.4 *Method Specifications*—Method specifications give the type of compaction equipment, fill material placement methods, and number of equipment passes to be used in compaction. Method specifications are based on the results of field compaction tests on trial test strips. The test strips are normally placed at the construction site with the equipment proposed for use and materials or sources that will supply fill material for the project. Method specifications have the advantage of providing continuous quality control through monitoring of the ongoing construction activities. If the material source changes or the material itself changes during construction, then the field testing should be repeated on the new material. Method specifications may also be useful for situations where variations in material properties make determination of the appropriate compaction curve difficult.

7.6.5 *Performance Specifications:*

7.6.5.1 *Fly Ash and FGD Material*—The compaction criteria are typically expressed as a percentage of the maximum dry density, in accordance with Test Method D698 or D1557, with a molding water content that does not exceed the optimum water content plus a given percentage and prevents dusting during placement and compaction. When static-type compaction is used, an allowable range of water content is also usually specified so that the material will be in the range where the required density can be readily achieved. Fly ash and FGD material have a tendency to be displaced under the mass of the compactor when placed with above the optimum water content. Specifications requiring placement over a range of water content less than the optimum water content will control this phenomenon. Experience has shown that vibratory compactors operating at the resonant frequency can achieve the required degree of compaction in a minimum of passes over a wide range of water content, but not when the material is excessively wet, that is, above the optimum water content. For FGD material that exhibits thixotropic properties, the performance specification will typically define the allowable layer thickness and strength requirements of samples tested in unconfined compression at specified time intervals.

7.6.5.2 *Bottom Ash and Boiler Slag*—Performance specifications for bottom ash or boiler slag typically specify the compaction criteria as a percentage of the relative density in accordance with Test Method D4254 and may require use of vibratory compaction equipment.

7.6.6 *Dust Control*—Dust control is accomplished when the molding water content of the CCP is sufficient to achieve the desired degree of compaction. CCP surfaces exposed to the sun and wind can dry out and become susceptible to dusting. Dusting can be controlled by wetting the CCP, applying a dust suppressant, constructing wind screens, or by placing the final soil cover.

8. Design Methods

8.1 *General*—The underlying materials and the CCP fill must support their own mass and the loads to be placed on them without excessive settlement and require no long-term maintenance beyond that typically exercised for the intended use. In addition, settlement due to the consolidation of the soils that lie beneath the fill must be evaluated and maintained within tolerable limits considering the intended use of the site. The process of analyzing these conditions for CCPs is similar to that normally followed for conventional natural soil materials. The procedure entails developing an analytical model of the fill and underlying soils and the relevant site conditions and determining whether expected physical behavior is within allowable limits. All design work and materials testing should be performed in accordance with established engineering practices and in accordance with applicable laws and regulations.

8.2 *Slope Stability*—As is done with conventional fill materials, analysis of slopes should consider possible failure of the CCP fill as well as failure of the foundation soils resulting from the load of the fill.

8.2.1 *Seepage and Drainage*—Variables including high water tables, seepage forces, seismic loadings, and excess pore pressures in foundation soils should be considered, as appropriate. Adequacy of drainage provisions to maintain the fill in a drained condition should be considered.

8.2.2 *Material Properties*—Material properties for CCPs should be as determined by laboratory testing. Characterization of site materials and conditions should be in accordance with Guide D420, with sampling, laboratory, and field testing conducted as appropriate.

8.2.3 *Stability Analysis*—Stability analyses are typically conducted for circular failure surfaces using the friction circle method, which is conservative for most cases. For situations where noncircular failure surfaces are to be analyzed, complex conditions are to be assessed, or more precise estimates are required, other appropriate procedures may be used.

8.3 *Settlement*—Settlement analyses should consider compression of the fill resulting from foundations and other loads placed on the structural fill as well as compression of the foundation soils beneath the fill due to the combined mass of the fill and the superimposed loads. Conventional methods of analysis are used as with natural soils.

8.4 *Bearing Capacity*—The ability of the fill to support structures bearing on or within the fill can be calculated by conventional procedures used for natural soils.

8.4.1 *Footings*—Ultimate bearing capacity analysis is appropriate for footings bearing on compacted CCP structural fills. The analysis is simplified by the drained, noncohesive nature of the fill (except for self-hardening fly ash and FGD material). The relatively low unit weight of CCPs as compared to natural soils should be considered in the analysis. Footings that are wider than the thickness of the fill below the footing or that are located near the edge of slopes are cases that may require special consideration.

8.4.2 *Slabs and Pavements*—The ability of the fill to support slabs and pavements to be located on the fill surface can be assessed by standard pavement design procedures and by determining the modulus of subgrade reaction by Test Method D1195 or D1196 or bearing ratio by Test Method D1883 or D4429, as appropriate.

8.5 *Lateral Earth Pressure*—Conventional methods of analysis of lateral earth pressure can be used for CCPs considering that the material is cohesionless (except for self-hardening CCPs) and has a lower density than many natural soils. For structures that are fixed and unable to yield, a rest coefficient of 0.5 is typically used in estimating loads. For most yielding retaining walls, active earth pressures are determined by Rankine's method. Coulomb's method is generally used for walls over 20 ft (6.1 m) in height.

9. Postplacement Monitoring

9.1 *General*—Postplacement monitoring is a valuable component of a mine reclamation application of CCPs because it is one means of documenting project success in terms of environmental impact. A postplacement monitoring program is needed for the life of the CCP placement activity and should provide for the determination of upgradient and downgradient water quality, thus monitoring methods should be sufficient to evaluate the performance of the placed CCP for potential environmental impact. The postplacement monitoring program, including scope and frequency, should be customized to each reclamation project to address site-specific issues such as, seasonal variations in water flow, specific CCB chemistry, and site hydrogeology. The parameters monitored should include metals and non-metals attributable to the CCP utilized.

9.2 *Water Quality*—Surface water, mine discharge, and ground water should be sampled and analyzed to determine water quality. All water quality samples should be analyzed for those chemical parameters deemed appropriate to characterize the water quality of the mine and surrounding site. These parameters should be identified prior to the pre-placement monitoring as noted in 5.5. Monitoring should be conducted at an appropriate frequency to ensure that any seasonal variations in water quality and flow are determined. The pre- and postplacement water quality data should be compared after sufficient postplacement data are collected as agreed upon with appropriate regulatory agencies. Data interpretation should include trend analyses of pre- and postplacement concentrations of chemical parameters of interest including standard deviation to aid in identifying outliers in the data set. Appropriate guidance for statistical analyses can be found as part of the EPA guidance under RCRA (**23**,**24**).

10. Keywords

10.1 beneficial use; coal combustion product; FBC product; FGD product; fly ash; highwall; pollution prevention; reclamation; recontouring; surface mine

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