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

ENGINEERING AND DESIGN MANUAL

COAL REFUSE DISPOSAL FACILITIES

Second Edition
May 2009
Rev. Aug. 2010

NOTE: Instructions for using this DVD version of the Manual are provided on the page ii.

MSHA
Mine Safety and Health Administration

Prepared by:

D'APPOLONIA ENGINEERING

RECORD OF REVISIONS

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Revision Date	Page	Comment
August 2010	6-144	Equation 6-18 correction
August 2010	6-151	Equation 6-23 definition of B for $4 < Cu < 8$
August 2010	7-83	Figure 7.22, Note 1 reference to Table 7.7
August 2010	8-51	Equation 8-13 correction
August 2010	9-30	Table 9.4 correction for size classification
August 2010	9-34	Typographical error
August 2010	9-37	Table 9.5 addition of WV and TX references
August 2010	R-14	Addition of reference (Howard, 1977)

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Suggestions for changes, corrections, or updates to the Manual should be directed to:

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The engineering guidance presented in this document has been compiled or developed by D'Appolonia Engineering under contract with the Mine Safety and Health Administration (MSHA) from referenced sources as well as input from MSHA and the coal industry. However, the guidance, recommendations, and conclusions presented herein may not necessarily represent the official policies of MSHA or the U.S. government.

Preface

This Manual presents guidance on procedures for use in the engineering design, construction monitoring, operation and inspection of coal refuse impoundments and embankments in the United States. It is an update of the original 1975 edition and reflects advances in engineering, construction, and facility monitoring and operations practices. The primary intent of the Manual is to serve as a uniform guide to safe refuse disposal practices for those concerned with coal mining and preparation. The Manual serves this purpose in several ways by: (1) providing experienced embankment dam design engineers with the characteristics of coal refuse and its disposal so that their experience can be appropriately applied; (2) providing specialized technical knowledge concerning embankment design in a form that can be used by engineers who do not specialize in this field; (3) updating geotechnical, structural, hydrologic and hydraulic design criteria for a range of embankment and impoundment conditions, and spillway and drainage structures; (4) providing guidance on disposal requirements and limitations for mine operators to include refuse disposal in the overall coal production operation; and (5) providing guidance on construction, operation, inspection, monitoring and instrumentation, and emergency action planning associated with the implementation of safe and reliable designs.

The 1975 edition of the Manual was prepared following the failure of a coal waste dam at Buffalo Creek, West Virginia, that resulted in 125 fatalities. This Manual update was prompted by the recognition that significant advances have been made in the fields of coal waste disposal and dam safety in the 30-plus years since the original Manual was published. Another impetus was an incident that occurred in Martin County, Kentucky, in 2000 in which over 300 million gallons of water and fine coal refuse from a slurry impoundment broke into an underground mine. Slurry subsequently flowed out of two mine openings and impacted streams in two separate watersheds. This incident prompted the U.S. Congress to provide funding to the National Research Council (NRC) to examine ways to reduce the potential for similar accidents. The NRC's report, "Coal Waste Impoundments: Risks, Responses, and Alternatives," which was released in 2002, included a number of recommendations for MSHA. One recommendation was that MSHA "continue to adopt and promote the best available technology and practices with regard to site evaluation, design, construction, and operation of impoundments." MSHA reported to Congress that one measure to address the NRC recommendations would be this updating of the original Coal Refuse Design Manual.

The guidance presented in this Manual represents information, methods and procedures that are recommended for consideration by designers, coal operators, and regulators. The guidance presented in this Manual is not regulation and cannot be enforced as such. It is not intended to preclude the application of other credible methods and procedures or the use of other and new information that will result in a safe and reliable coal refuse disposal facility. It is the responsibility of the designer to investigate the requirements of the project, recognize the unique and critical aspects of the site conditions, and prepare designs that reflect actual site conditions, features, loadings, and constraints.

In this update of the Manual, new chapters have been developed on seismic design and on site mining and foundation issues, two topics that can have an impact on the type of disposal facility designed. The long operating life of coal refuse facilities makes monitoring of embankment behavior and facility maintenance particularly important. The sections on operation, monitoring, and instrumentation summarize procedures and devices to aid the designer and operator for defining and implementing an appropriate field observation program. In addition, general guidance is provided for the preparation of emergency action plans. These plans are recommended for certain dams and impoundments,and are required by some state regulatory agencies and encouraged by MSHA as part of addressing hazardous conditions under 30 CFR § 77.216-3.

In addition to concern for safety, the Manual addresses environmental considerations and controls that may influence the design of embankments and impoundments. Executive Order 11514 – Protection and Enhancement of Environmental Quality, dated March 5, 1970, requires all Federal agencies to "Monitor, evaluate and control on a continuing basis their agencies' activities so as to protect and enhance the quality of the environment. Such activities shall include those directed to controlling pollution and enhancing the environment and those designed to accomplish other program objectives which may affect the quality of the environment." The Manual does not present guidance in establishing criteria for environmental controls (e.g., hydraulic conductivity of liner systems), because such guidance is more appropriately left to other references and regulatory agencies.

This Manual is intended to provide the designer with an important source of information. However, the text and accompanying figures, tables and references should not be applied without proper engineering knowledge and judgment. Responsibility for actual design lies with the Professional Engineer in responsible charge of the work. The use or application of the methods and information contained herein is strictly the responsibility of the person utilizing the material. Designs should be based on sound engineering principles and judgment and reflect actual site conditions, and they should not merely be patterned after a successful design used at another location or possibly portrayed in the Manual. The designer should be diligent and recognize that advances in approaches, criteria, and methods will occur that may affect the applicability of portions of any reference or design guide.

This Manual was prepared by engineers and scientists with background and experience in the subject matter, with input from MSHA personnel who review design plans and conduct investigations at disposal sites. Overall direction and technical content were provided by Mr. Robert E. Snow of D'Appolonia Engineering. Manual coordination was performed by Dr. James L. Withiam, D'Appolonia, and final editing of the text was provided by Dr. J. Timothy Onstott. Proper recognition to the entire Project Team and D'Appolonia staff for their devoted efforts is not possible here. The main contributors to and reviewers of technical chapters are noted in Table 1.

Special recognition is also given to Mr. John W. Fredland, Dam Safety Officer for MSHA, as the contracting officer's technical representative, Mr. Harold L. Owens, Mr. George H. Gardner, and to other MSHA personnel who provided many valuable comments in suggesting content and reviewing the text for publication. Finally, grateful appreciation is given to those in industry who provided input and review comments during the process of preparation of this document. This includes input from the National Mining Association and its consultants, as well as federal and state agencies and universities.

This Manual is available in hard copy and DVD. The DVD format includes hyperlinks and search capabilities using Adobe Acrobat Reader software. Hyperlinks allow the display of the highlighted citation of a figure, table, appendix, or selected reference in the text. Selected references (in PDF format) that are available in the public domain are included on the DVD version. For references not in the public domain, reasonable efforts were made to obtain copyright permission. No hyperlink is provided for references of substantial size, lack of availability in the public domain, or where permission for reprint could not be obtained. The complete citation for all references is provided in the References section.

TABLE 1 MAJOR AND EXPERT CONTRIBUTORS AND REVIEWERS

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For any suggested changes, corrections or updates, commenters should identify specific pages, paragraphs, tables, or figures within the Manual, along with proposed replacement or new material. Sources of proposed material should be completely cited, along with permission for use in a future revised edition of this document.

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Acronyms

ACRONYM	REPRESENTS
AASHTO	American Association of State Highway and Transportation Officials
ABS	Acrylonitrile-Butadiene-Styrene
ACI	American Concrete Institute
AC	alternating current
ALD	anoxic limestone drain
AMC	antecedent moisture condition
AMD	acid mine drainage
AMRL	AASHTO Materials Reference Laboratory
AOS	apparent opening size
ArcGIS	GIS software developed by Environmental Systems Research Institute (ESRI)
ARMPS	Analysis of Retreat Mining Pillar Stability (software)
ARMPS-HWM	ARMPS program for highwall mine pillars (software)
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BOD	biochemical oxygen demand
BREACH	breach parameter computation software
CADD	computer-aided design and drafting
CANDE	Culvert Analysis and Design (software)
CD	consolidated drained
CGS	Canadian Geotechnical Society
CIDC	consolidated isotropic drained compression
CISPM	Comprehensive and Integrated Subsidence Prediction Model (software)
CIUC	consolidated isotropic undrained compression
CLSM	controlled low-strength material
CMP	corrugated metal pipe
CMRR	Coal Mine Roof Rating (software)

ACRONYM	REPRESENTS
CN	curve number
CO	carbon monoxide
COSMOS	Consortium of Organizations for Strong-Motion Observation Systems
COV	coefficient of variability
CPE	chlorinated polyethylene
CPM	Critical Path Method (software)
CPP	corrugated plastic pipe
CPT	cone penetrometer test
CPTu	piezocone penetrometer test
CRR	cyclic resistance ratio
CFR	Code of Federal Regulations
CSI	Construction Specifications Institute
CSPE	chlorosulfonated polyethylene
CSR	cyclic stress ratio
CU	consolidated undrained
$\overline{CU}$	consolidated undrained with pore pressure measurements
CWA	Clean Water Act
DAMBRK	Dam Break (software)
DC	direct current
DCDT	direct current differential transformer
DEM	digital elevation model
DEP	Department of Environmental Protection (state environmental agencies)
DI	degradation index
DMLR	Virginia Department of Mines, Minerals, and Energy, Division of Mined Land Reclamation
DOD	Department of Defense
DOQ	digital orthophoto quadrangle
DOQQ	digital orthophoto quarter quadrangle
DRG	digital raster grid
DSHA	deterministic seismic hazard analysis
DWOPER	Dynamic Wave Routing Model (software)
EAP	Emergency Action Plan
EDM	electronic distance measuring

ACRONYM	REPRESENTS
EEGS	Environmental and Engineering Geophysical Society
EERT	Eastern Energy Resources Team
EM	electromagnetic method
EMA	Emergency Management Agency
EMC	Emergency Management Coordinator
EMS	Emergency Medical Service
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
EROS	Earth Resources Observation and Science
ESRI	Environmental Systems Research Institute
FBC	fluidized bed combustion
FE	finite element
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FGD	flue gas desulfurization
FHWA	Federal Highway Administration
FLAC	Fast Lagrangian Analysis of Continua (software)
FLDWAV	Flood Wave (software)
FLUSH	seismic soil-structure interaction software
FR	friction ratio
FS	factor of safety
FVST	field vane shear test
GAI-LAP	Geosynthetic Accreditation Institute - Laboratory Accreditation Program
GCL	geosynthetic clay liner
GEI	Geotechnical Engineers, Inc.
GIS	geographic information system
GPR	ground penetrating radar
GPS	global positioning system
GRM	generalized reciprocal method
HDPE	high-density polyethylene
HEC	USACE Hydrologic Engineering Center
HEC-1	open channel flow analysis software
HEC-GeoHMS	GIS -based version of HEC-HMS software

ACRONYM	REPRESENTS
HEC-HMS	Hydraulic Engineering Center Hydrologic Modeling System (software)
HEC-RAS	Hydraulic Engineering Center River Analysis System (software)
HMR	Hydrometeorological Report
HSG	hydrologic soil group
ICODS	Interagency Committee on Dam Safety
IDF	inflow design flood
LAMODEL	software for computing stresses and displacements in mines
LI	liquidity index
LIDAR	light detection and ranging
LL	liquid limit
LLNL	Lawrence Livermore National Laboratory
LVDT	linear variable differential transformer
MAE	Mid-America Earthquake
MARV	minimum average roll value
MCE	maximum credible earthquake
MDE	maximum design earthquake
MIBC	methylisobutyl carbinol
MMI	Modified Mercali Intensity
MPBX	multiple-point borehole extensometer
MSF	magnitude scaling factor
MSHA	Mine Safety and Health Administration
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCB	National Coal Board (Britain)
NEH	National Engineering Handbook
NEHRP	National Earthquake Hazard Reduction Program
NIOSH	National Institute for Occupational Safety and Health
NMO	normal moveout
NMSZ	New Madrid Seismic Zone
NOAA	National Oceanic and Atmospheric Administration
NR	not reported
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation

ACRONYM	REPRESENTS
NSSGA	National Stone, Sand and Gravel Association
NWS	National Weather Service
OBE	operating basis earthquake
OLC	open limestone channel
OSHA	Occupational Safety and Health Administration
OSM	Office of Surface Mining
PCCP	prestressed concrete cylinder pipe
PCPT	piezocone penetrometer test
PE	polyethylene
PERT	scheduling software
PGA	peak ground acceleration
PI	plastic index
PL	plastic limit
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PMTS	Probable Maximum Thunderstorm
POA	percent open area
PSHA	probabilistic seismic hazard analysis
PV	prefabricated vertical
PVC	polyvinyl chloride
Q	equivalent to UU
QA	quality assurance
QC	quality control
QUAD4	software for finite element seismic analysis of earth structures
R	equivalent to $\overline{CU}$
RCCP	reinforced concrete cylinder pipe
RCP	reinforced concrete pipe
RMR	rock mass rating
RQD	rock quality designation
RVSP	reverse vertical seismic profile
S	equivalent to CD
SAGEEP	Symposium on the Application of Geophysics to Engineering and Environmental Problems

ACRONYM	REPRESENTS
SAPS	successive alkalinity producing system
SCPTu	seismic piezocone penetrometer test
SCS	Soil Conservation Service (now NRCS)
SDI	slake durability index
SDPS	Surface Deformation Prediction System (software)
SEE	safety evaluation earthquake
SF	safety factor (for channel linings)
SHAKE	software for seismic analysis of subsurface layers
SHANSEP	stress history and normalized soil engineering parameters
SL	shrinkage limit
SMCRA	Surface Mining and Reclamation Act
SMPDBK	Simplified Dam Break (software)
SP	spontaneous or self potential
SPBX	single-point borehole extensometer
SPECTEXT	specification software
SPT	standard penetration test
SSE	safe shutdown earthquake
SSHAC	Senior Seismic Hazard Analysis Committee
TDEM	time-domain electromagnetic method
TDR	time-domain reflectometry
TR	technical release
USACE	U.S. Army Corps of Engineers
USBM	U.S. Bureau of Mines
USBR	U.S. Bureau of Reclamation
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USNRC	U.S. Nuclear Regulatory Commission
UU	unconsolidated undrained
VLDPE	very low density polyethylene
VLF	very low frequency

ACRONYM	REPRESENTS
VST	vane shear test
VSP	vertical seismic profile
WMS	Watershed Modeling System (software)
WP	wetted perimeter
WVDOT	West Virginia Department of Transportation