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USACE / NAVFAC / AFCEC **UFGS-02 56 13.16 (February 2025)**

Preparing Activity: USACE **Superseding**
UFGS-02 56 13.16 (February 2021)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2025
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CLAY WASTE CONTAINMENT

02/25

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SECTION 02 56 13.16

CLAY WASTE CONTAINMENT
02/25

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NOTE: This guide specification covers the requirements for construction of a clay barrier layer (liner and cover) to isolate contaminated material from the environment.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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PART 1 GENERAL

1.1 UNIT PRICES

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NOTE: These paragraphs should be edited based on whether the contract will use a single job price or unit prices. If there is a separate Measurement and Payment section, edited versions of these paragraphs should be inserted in that section.

Weight measurement may be used to supplement volume measurement surveys if significant subgrade settlement (landfill cover applications) is anticipated.

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Base measurement and payment for the clay barrier layer on the unit price schedule for each cubic meter cubic yard of clay in place. Include the cost for development of the clay borrow source, cost of clay, excavation, hauling, equipment, placement, testing, and other incidental work required to construct the clay barrier layer in this unit cost.

1.2 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this Specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D698	(2012; R 2021) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu. ft. (600 kN-m/cu. m.))
ASTM D1140	(2017) Standard Test Methods for Determining the Amount of Material Finer than 75-µm (No. 200) Sieve in Soils by Washing
ASTM D1556/D1556M	(2015; E 2016) Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
ASTM D1557	(2012; E 2015) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3) (2700 kN-m/m3)
ASTM D1587/D1587M	(2015) Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
ASTM D2167	(2015) Density and Unit Weight of Soil in

	Place by the Rubber Balloon Method
ASTM D2216	(2019) Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D2488	(2017; E 2018) Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)
ASTM D4220/D4220M	(2014) Preserving and Transporting Soil Samples
ASTM D4318	(2017; E 2018) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D5084	(2016a) Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
ASTM D6913/D6913M	(2017) Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
ASTM D6938	(2017a) Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM E329	(2023) Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection
INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)	
ISO ISO/IEC 17025	(2017) General Requirements for the Competence of Testing and Calibration Laboratories
U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)	
EPA 505-B-04-900A	(2005) Intergovernmental Data Quality Task Force - Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs Part 1: UFP-QAPP Manual
EPA SW-846	(Third Edition; Update VII) Test Methods for Evaluating Solid Waste: Physical/Chemical Methods
UFP-QAPP WKSTS	(2012) Intergovernmental Data Quality Task Force - Uniform Federal Policy for Quality Assurance Project Plans, Optimized UFP-QAPP Worksheets

1.3 SYSTEM DESCRIPTION

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NOTE: Describe other components of the liner or cover system and reference specification Sections that contain the requirements for these components. Other specification sections that may be included in a liner or cover project are: Section 02 56 13.13 GEOMEMBRANE WASTE CONTAINMENT, Section 02 56 13.19 GEOSYNTHETIC CLAY LINER WASTE CONTAINMENT, Section 02 66 13 SELECT FILL AND TOPSOIL FOR LANDFILL COVER, and Section 02 66 16 TEST FILL.

State regulations may provide for different hydraulic conductivity than the value recommended below.

If this guide specification is being prepared to include requirements for both a liner and cover system on the same project, the Designer should ensure that appropriate edits are made throughout the specification section to identify requirements that are specific to either the liner or cover component (e.g. a liner may have different thickness and hydraulic conductivity requirements that a cover).

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Construct a clay waste containment[liner][cover] layer consisting of a minimum [_____] inch thick compacted clay with a hydraulic conductivity of less than [1 x 10^{-7}][_____] cm/s.

[1.4 PRE-INSTALLATION MEETING

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NOTE: Delete this paragraph if a separate specification section is developed for the entire project to cover pre-installation meetings and other administrative requirements.

****

Conduct a pre-installation meeting at the jobsite [at least five business days prior to the start of earthwork operations on the project][_____]. The pre-installation meeting is to be arranged by the Contractor and is to follow the written pre-installation meeting agenda submitted prior to the meeting. The purpose of this meeting is to review the requirements of this Specification and the associated plans. The following individuals must be in attendance at this meeting: Contractor's Project Manager and Project Superintendent, earthwork subcontractor's Project Manager and Site Foreman, Contractor's Geotechnical Engineer and Testing Agency, Government Geotechnical Engineer and Civil Engineer, and Government Construction Manager and Engineering Technician.

Record pre-installation meeting minutes and publish by way of email within 48 hours to all attendees. The minutes must be re-published within 48 hours pending any subsequent comments from the attendees.

]1.5 SUBMITTALS

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NOTE: Review submittal description (SD) definitions

in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Pre-Installation Meeting Agenda

Pre-Installation Meeting Minutes; G, [_____]

Uniform Federal Policy Quality Assurance Project Plan (UFP-QAPP); G, [_____]

Material Handling Plan; G, [_____]

Borrow Source Assessment Report; G, [_____]

SD-04 Samples

Clay

SD-06 Test Reports

Water Supply Analysis

Clay Material Laboratory And Field Test Results

Moisture Content and Density Tests of Clay

Hydraulic Conductivity Tests of Clay

Geotechnical Evaluation Report; G, [_____]

SD-07 Certificates

Qualifications; G, [_____]

Certificate Of Subgrade Acceptance; G, [_____]

1.6 QUALITY CONTROL

1.6.1 Regulatory Requirements

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NOTE: Regulatory requirements will be location specific and may include local ordinances and State regulatory requirements. At a minimum, an approved Soil Erosion and Sediment Control Plan will be required by the local Soil Conservation District.

For sites addressed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), administrative permit requirements for on-site activities are not required, though the substantive requirements may need to be met. The permits or permit equivalents may include those addressing air emissions, water discharge, stormwater pollution prevention, and possibly others. Permitting requirements known to have substantive requirements should be listed here. If permit requirements are covered in other specifications, such as Section 01 57 19 TEMPORARY ENVIRONMENTAL CONTROLS, delete this section.

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Obtain all State and Local [permits][permit equivalents] required to perform the work.

1.6.2 Qualifications

Provide a Professional Geotechnical Engineer licensed in the [applicable jurisdiction][state that work is being performed] to provide inspection of the clay barrier layer throughout construction. The Geotechnical Engineer must have [five][_____] years of experience in design, construction, Quality [Assurance][Control], or certification of [landfill][dump] liners including low permeability clay barrier liners. The Geotechnical Engineer is responsible for performing pre-construction, periodic during construction, and final at completion of construction site visits to inspect and [approve][certify] that the clay barrier layer meets specifications. The Geotechnical Engineer is responsible for preparing and updating the Materials Handling Plan and Borrow Source Assessment Report as construction progresses to reflect changing conditions and submit updated plans if necessary. Submit a [monthly][_____] Geotechnical

Evaluation Report, informing the Contractor and Contracting Officer of the status of the plans and an accounting of the Contractor's adherence to the plans addressing any present or potential problems. The Contractor is responsible for arranging meetings with the Geotechnical Engineer and Contracting Officer throughout the contract duration.

1.6.3 Qualified Technician

Provide a Qualified Technician to inspect, monitor, sample, and perform field testing. The technician qualifications need to be one of the following: a current National Institute for Certification in Engineering Technologies (NICET) Level II minimum certification in Construction Materials Testing Soils; Professional Civil or Geotechnical Engineer with minimum [two][_____] years of experience in design, construction, Quality [Assurance][Control], or certification of [landfill][dump] liners including low permeability clay barrier liners.

1.6.4 Lab Validation

Perform testing by an accredited commercial testing laboratory meeting the requirements listed below. Items a-c apply to testing laboratories used for soil geotechnical testing (all tests other than chemical contamination tests). Item d applies to testing laboratory used for chemical contamination tests. Submit testing laboratory validation for the testing to be performed. Do not permit work requiring testing until the Contracting Officer approves use of the testing laboratory.

a. Comply with applicable requirements of ASTM E329.

b. Testing laboratory must be licensed to operate in the State of [_____]. Third party laboratory testing must be conducted by a laboratory either validated by the USACE Materials Testing Center or have an AASHTO Materials Reference Laboratory (AMRL) certification for the required tests.

c. Testing equipment used by laboratory must be calibrated at maximum intervals of 12 months by devices of accuracy traceable to one of the following: NIST Standard Reference Materials, ISO ISO/IEC 17025, certified by state or local bureau.

d. Perform the testing in paragraph CHEMICAL CONTAMINATION TESTING by a DoD Environmental Laboratory Accreditation Program (DoD ELAP) accredited commercial testing laboratory meeting the requirements of [Section 01 45 00 QUALITY CONTROL][_____] and approved by the Contracting Officer. Submit testing laboratory validation for the testing to be performed. Do not permit work requiring testing until the Contracting Officer approves use of the testing laboratory.

1.7 DELIVERY, STORAGE, AND HANDLING

1.7.1 Delivery

Deliver clay to the site in trucks that meet all local, state, and federal transportation regulations[and have added containment of material in the form of a fabric cover to prevent spillage].

1.7.2 Storage

Keep stockpiles in a neat and well drained condition, giving due

consideration to drainage at all times. Clear and grub the ground surface at stockpile locations. Protect stockpiles from contamination from unsuitable materials, including but not limited to soils not meeting the definition of Clay defined in this Specification, volunteer vegetation growth, or windblow waste [material][debris], which may destroy the quality and fitness of the clay material. If the Contractor fails to protect the stockpiles, and any clay material becomes unsatisfactory, remove and replace such material with satisfactory clay material from approved sources. Unsatisfactory materials include materials which do not comply with the requirements for satisfactory materials in this Section, and also include man-made fills; trash; refuse; backfills from previous construction; roots and other organic matter or frozen material. Do not place stockpiles on prepared subgrade or any portion of the prepared subgrade or clay barrier layer. Place a [geotextile][geocomposite][____] beneath stockpiles and between stockpiles of dissimilar material to keep materials separated. Provide stormwater sediment and erosion controls in accordance with[Section 01 57 19 TEMPORARY ENVIRONMENTAL CONTROLS][_____]. Do not allow water to pond in the stockpile areas.

1.8 [PROJECT][SITE] CONDITIONS

1.8.1 Environmental Requirements

Do not install the clay barrier layer when temperatures are below freezing or during precipitation events. Do not install the clay barrier layer when the subgrade is frozen, excessively wet, or extremely dry such that the subgrade compaction requirements in paragraph SUBGRADE EXAMINATION AND PREPARATION cannot be met, or in a condition otherwise detrimental to proper grading. Any relaxation of this requirement must be approved by the Contracting Officer.

1.8.2 Existing Conditions

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NOTE: Existing conditions are site specific and are generally shown on the plans and provided in design or investigation documents prepared for the site. If there are specific conditions the Contractor should be made aware of that are contained in plans or documents provided, describe here.

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The existing site conditions are presented [in Appendix [_____]][on the Drawings]. Immediately notify the Contracting Officer if there are discrepancies between the existing site conditions as presented and field conditions discovered during execution.

PART 2 PRODUCTS

2.1 EQUIPMENT

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NOTE: A soil stabilizer or road regrader is often specified for use on soils that have clods or particles which are difficult to reduce to an acceptable size.

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Do not operate equipment to place the clay barrier layer by braking

suddenly, turning sharply, or traveling at speeds exceeding 8 km 5.0 miles per hour.

2.1.1 Compaction Equipment

Use compaction equipment consisting of tamping foot compactors which have a minimum weight of [20,500][_____] kg [45,000][_____] pounds. Provide at least one tamping foot for each [81,000][_____] square mm [126][_____] square inches of drum surface. The length of each tamping foot, from the outside surface of the drum, must be [25][_____] mm [1][_____] inch greater than the loose lift thickness to assure proper permeability between lifts. During compaction operations, keep the spaces between the tamping feet clear of materials which would impair the effectiveness of the tamping foot compactors.

2.1.2 Scarification Equipment

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NOTE: Tamping foot compactors create a roughened surface on each lift of clay. The designer must determine if scarification is required to further roughen the surface of the clay barrier layer prior to placement of additional lifts of clay. If additional scarification is not required, omit this paragraph and other references to scarification throughout this section.
****

Provide disks, rotor tillers, [stabilizers][reclaimers], or other approved means to scarify the surface of each lift of clay prior to placement of the next lift. Provide scarification equipment capable of controlling depth to uniformly disturb the upper 25 mm 1 inch of each lift of the clay barrier layer to provide bonding, elimination of failure planes, and to assure continuous homogenous hydraulic conductivity between lifts.

2.1.3 Steel Wheeled Rollers

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NOTE: The upper surface of the clay barrier layer must be smooth rolled if a geosynthetic will be placed on top of the clay barrier layer. Smooth rolling is also required to control moisture (precipitation infiltration or drying out) of the clay barrier layer between placement of lifts.
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Use a smooth, non-vibratory steel wheeled roller to produce a smooth compacted surface on the clay barrier layer and to prevent moisture intrusion or drying. Steel wheeled rollers less than [9,070][_____] kg [20,000][_____] pounds are not acceptable.

2.1.4 Hand Operated Tampers

Provide hand operated tampers consisting of rammers or other impact type equipment. Vibratory plate-type equipment will not be allowed.

2.2 MATERIALS

2.2.1 Clay

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NOTE: The physical criteria listed in Table 1 are minimum requirements. More restrictive criteria may be appropriate depending on local soils. For composite geomembrane/clay covers and liners, the maximum particle size should be reduced to 13 mm 0.5 inches in the upper lift of clay barrier layer to prevent puncturing of the geomembrane.

Bentonite is often added to soils that do not contain enough clay to achieve the desired hydraulic conductivity. Refer to EPA/600/R-93/182 - Quality Assurance and Quality Control for Waste Containment Facilities if bentonite will be used as an additive to the available soils.

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Provide clay that has a Unified Soil Classification System classification (USCS) of CH, CL, or SC and is free of roots, debris, organic or frozen material. Clay material must comply with the criteria listed in Table 1. Submit a minimum of 23 kg 50 pounds of clay from each proposed borrow source to the Government at least [15][_____] business days prior to placement; this material is for possible Government Quality Assurance testing and not the Quality Control testing required by the Contractor.

TABLE 1 - REQUIRED PHYSICAL PROPERTIES OF CLAY

PROPERTY	TEST VALUE	TEST METHOD
Max. particle size	[25][__] mm[1][__] inch	ASTM D6913/D6913M
In Contact With Geomembrane Max. particle size	[13][_____] mm [1/2][_____] inch	ASTM D6913/D6913M
Min. percent passing 4.75 mm No. 4 sieve	[80] [_____]	ASTM D6913/D6913M
Min. percent passing 0.075 mm No. 200 sieve	[50] [_____]	ASTM D1140
Min. liquid limit	[35] [_____]	ASTM D4318
Min. plasticity index	[10] [_____]	ASTM D4318
Max. plasticity index	[30] [_____]	ASTM D4318

2.2.2 Water

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NOTE: Two options are provided. The first option is to only allow the Contractor to use potable water. The second option allows the Contractor to use non-potable water, but includes a testing requirement to limit the chance that the Contractor supplies a water that could introduce contaminants into the clay barrier layer. The first option is simpler, but could lead to higher project costs if the volume of water needed is significant and/or potable water sources are not readily available. When specifying the criterion to be met for water, the Designer should consider if there are other standards which are more appropriate for the specific project (e.g. state groundwater cleanup criteria).

****

Supply water used to increase moisture content of the clay barrier layer for the sake of compaction during installation. Maintain an accurate record of water usage.[Use only potable water from a regulated public water system.][If non-potable water is to be used, provide water that does not contain oils, acids, salts, alkalis, organic matter, solids, or other substances at concentrations that could be detrimental. Also characterize non-potable water prior to its use by collecting a sample from the water source and analyzing according to Table 2. Submit a Water Supply Analysis demonstrating that water meets requirements.

TABLE 2 - MOISTURE CONDITIONING AND DUST CONTROL WATER CRITERIA

ANALYTICAL METHOD NUMBER (From EPA SW-846; use current version)	ANALYSIS TYPE	CRITERIA TO BE MET
6010 [and 7470A]	Metals [and Mercury]	[Less than Maximum Contaminant Level (MCL)][_____]
8260	Volatile Organics	
8270	Semi-volatile Organics	
8082	PCBs	
1633	PFAS	
8081	Pesticides	
Within each Analytical Method, only analyze for analytes which have an [MCL][_____].		

]

2.3 TESTS, INSPECTIONS, AND VERIFICATIONS

2.3.1 Borrow Source Assessment

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NOTE: Shear strength testing is often required for landfill covers and liners which contain geosynthetics. Testing should be conducted on all

potential slip interfaces. Criteria for shear strength testing (also referred to as interface friction testing) are described in Section 02 56 13.13 GEOMEMBRANE WASTE CONTAINMENT or Section 02 56 13.19 GEOSYNTHETIC CLAY LINER WASTE CONTAINMENT.

The testing defined in paragraphs MOISTURE-DENSITY (COMPACTION) TESTING and HYDRAULIC CONDUCTIVITY TESTING is performed to determine the acceptable zone of moisture and compaction to assure that hydraulic conductivity of the clay barrier layer meets requirements; this testing is not to assure structural compaction of the soil. The compaction and moisture testing utilized in field quality control is used to indirectly determine hydraulic conductivity through plotting on the developed acceptable zone.

****

Perform borrow source assessment tests on each principal type and combination of materials proposed for use in the clay barrier layer to assure compliance with specified requirements and to develop compaction requirements for placement. Perform one set of borrow assessment tests for each [400][_____] cubic meters [500][_____] cubic yards for each borrow source proposed. Perform at least three borrow assessment tests for each soil type and borrow source. A set of borrow source assessment tests is comprised of classification testing, moisture-density (compaction) testing, and hydraulic conductivity testing.

2.3.1.1 Classification Testing

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NOTE: Test pits should be used, if possible, because they provide a better method of characterizing borrow sources than borings.

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Use [test pits][borings] placed in a grid pattern to characterize each proposed borrow source. Extend the [test pits][borings] to the full depth of the proposed borrow source. Perform visual classification as described in ASTM D2488 over the full depth of each [test pit][boring] by the [Geotechnical Engineer described in paragraph GEOTECHNICAL ENGINEER][Qualified Technician described in paragraph QUALIFIED TECHNICIAN]. Group soils into "principal types" based on visual classification. Perform classification testing on representative samples of each principal type and combination of materials. Classification testing consists of the tests identified in the table in paragraph CLAY.

2.3.1.2 Moisture-Density (Compaction) Testing

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NOTE: A minimum of two compaction efforts are recommended to adequately define the relationship between moisture-density and hydraulic conductivity.

****

Test representative samples from each principal type and combination of borrow materials to establish compaction curves using ASTM D698 and

ASTM D1557. Use a minimum of [five][_____] points to develop each compaction curve. Plot the compaction curves for each principal type and combination of borrow materials on a single graph of dry density versus moisture content.

2.3.1.3 Hydraulic Conductivity Testing

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NOTE: When performing hydraulic conductivity testing, the average effective confining pressure should be representative of post construction conditions. The minimum effective confining pressure should be equal to or greater than 21 kPa 3 psi to avoid side wall leakage.

If the clay barrier layer will be placed beneath hazardous waste, chemical compatibility testing may be appropriate. Chemical compatibility testing consists of performing hydraulic conductivity tests on the clay liner material using a representative leachate sample as the permeant.

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Perform hydraulic conductivity tests on representative samples of each principal type and combination of borrow materials. A set of tests is comprised of one hydraulic conductivity test run on a representative sample corresponding to each point from each compaction curve (ASTM D698 and ASTM D1557) at or above ASTM D1557 optimum moisture content. Conduct hydraulic conductivity testing referenced in this Section in accordance with ASTM D5084. In addition, adhere to the following procedures when performing the hydraulic conductivity testing:

a. Verify saturation of test specimens by determining the B coefficient. The B coefficient must be at least 0.95. The B coefficient is defined as the change in pore water pressure divided by the change in confining pressure.

b. During consolidation of the test specimens, record outflow volumes versus time on a semi-log graph to confirm primary consolidation has been completed prior to permeation of the specimens.

c. Use a permeant of 0.01 molar calcium chloride solution created from deaired, deionized water as specified in ASTM D5084 for back pressure saturation and permeation.

d. Provide an average effective confining pressure of [_____] kPa [_____] psi.

2.3.1.4 Chemical Contamination Testing

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NOTE: This section includes a requirement to prepare a UFP-QAPP to define chemical contamination testing. Alternatively, this section may reference a separate specification section in the project requiring preparation of a UFP-QAPP. If that is the case, ensure that UFP-QAPP requirements from this section are appropriately incorporated into the separate specification section.

Suggested chemical analyses, sampling frequency, sample collection methods, and chemical concentration screening level standards are included as optional requirements to be considered in the UFP-QAPP. The Designer can include more specific requirements in the list of UFP-QAPP elements to be addressed. Individual states where work is being completed may have requirements that should also be considered.

The Designer should take care that requirements are not too strict for what is considered "clean" soils. Natural and anthropogenic background concentrations of chemicals should be considered in addition to health-based screening levels defined by regulatory agencies. The Designer may wish to use alternative methods instead of conducting project-specific specific chemical contamination testing; alternative methods could include using previously approved borrow sources where chemical contamination testing has already been conducted or using borrow sources where chemical contamination is not suspected based on knowledge of land use, etc.

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2.3.1.4.1 Uniform Federal Policy Quality Assurance Project Plan

Prepare a Uniform Federal Policy Quality Assurance Project Plan (UFP-QAPP) in accordance with the requirements set forth in EPA 505-B-04-900A and using the UFP-QAPP WKSTS. Submit the UFP-QAPP within [30][_____] calendar days after notice to proceed. Do not perform chemical contamination testing until the UFP-QAPP is approved. Prepare [draft for Government review][draft-final for [regulatory][_____] review] and final versions of the UFP-QAPP. Allow [30][_____] calendar days for [Government] review [and [30][_____] calendar days for regulatory review]. Allow [45][_____] calendar days for comment resolution following each review and preparing the next version of the document. Tailor the content to the requirements of the project and the site conditions. The UFP-QAPP must specifically address the following elements:

a. Chemical analyses: Specify the chemicals to be analyzed in each sample. [At minimum the following analyses must be included: [target compound list volatile organic compounds][target compound list semi-volatile organic compounds][target analyte list metals][pesticides/polychlorinated biphenyls][_____].]

b. Acceptable chemical concentrations for the clay barrier layer soils. [At minimum the following standards must be considered: [U.S. Environmental Protection Agency Regional Screening Levels][state-specific screening levels defined at [_____]][background chemical concentrations defined at [_____]].]

c. Chemical contamination sampling frequency. Assume a minimum sampling frequency of one sample for every [2,000][_____] cubic meters [2,500][_____] cubic yards of clay brought on site. Consider other sampling frequency requirements such as state regulations or guidance.

d. Sample collection method (e.g. discrete grabs, composites, incremental

samples).

e. Borrow source chemical contamination acceptance criteria, indicating how sample results will be compared to acceptable chemical concentrations to determine if the borrow source is acceptable (e.g. each sample must meet acceptable concentrations, average of samples must meet acceptable concentrations).

2.3.1.4.2 Chemical Contamination Sampling and Analysis

Sample and analyze each proposed borrow source for chemical contamination in accordance with [the UFP-QAPP][_____]. Any deviations to sampling frequency, number of samples, or sample collection methods must be [established in the approved [UFP-QAPP][_____]][approved by the Contracting Officer].

2.3.1.5 Borrow Source Assessment Report

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NOTE: Additional testing may be required to determine the "Acceptable Zone" based on shear strength considerations. The Designer would need to modify the Acceptable Zone requirement listed below in that case. For more discussion on this approach, see Chapter 3.4 of Waste Containment Facilities, Guidance for Construction Quality Assurance and Construction Quality Control of Liner and Cover Systems, 2nd Edition, 2007 (ASCE Press).

Experience with some materials indicates that the Acceptable Zone can be expanded to include soils that are 1-2 percent less than optimum moisture content while still achieving the require hydraulic conductivity. This would represent a less conservative approach, but one that could be less costly and difficult to achieve.

****

Submit a Borrow Source Assessment Report at least [15][_____] business days prior to clay placement. Do not place clay until the Borrow Source Assessment Report is approved. Include the following in the report:

a. Location of each borrow source.

b. Plan view and estimated available quantity of clay.

c. Locations and logs of subsurface explorations.

d. Laboratory test results.

e. Acceptable Zone of moisture contents and densities, displayed with the compaction curve graphs for each principal type of borrow material and combination of borrow materials. The Acceptable Zone is comprised of moisture-density values that meet the following requirements: maximum hydraulic conductivity = [1 x 10^{-7} cm per second][_____]; the minimum allowable moisture content must be no less than [optimum moisture content][_____] and no greater than [four][_____] percent above optimum based on ASTM D1557; the minimum allowable density must be no less than [90][_____] percent of maximum dry density based on ASTM D698.

f. Chemical testing data demonstrating that clay material is acceptable.

PART 3 EXECUTION

3.1 SUBGRADE EXAMINATION AND PREPARATION

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NOTE: An example Certificate of Subgrade Acceptance can be found in the USACE Engineering Manual (EM) 1110-1-4011.
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3.1.1 Examination

Each day during placement of the clay barrier layer, the Qualified Technician[and Government QA representative] must inspect the subgrade to verify it is acceptable for placement of the clay barrier layer. Examine the subgrade for compliance with the items in the list below. If subgrade is not suitable to place the clay barrier layer, prepare the subgrade in accordance with paragraphs CLEARING AND GRUBBING, GRADING, SUBGRADE COMPACTION, and PROOF ROLLING. Inspect and submit a Certificate of Subgrade Acceptance each day that the clay barrier layer is placed.

a. A project-qualified land surveyor has verified the lines and grades of the subgrade meet project design.

b. All CQC and CQA of the underlying geosynthetics has been completed and results have been accepted by the Contracting Officer.

c. The subgrade is free of irregularities, protrusions, loose soil, and abrupt changes in grade. The subgrade is free of vegetation and ruts and is not wet or frozen.

d. All tools, equipment, and temporary covers have been removed from the geosynthetic.

3.1.2 Clearing and Grubbing

[Clear and grub in accordance with Section 31 11 00 CLEARING AND GRUBBING.] Remove trees, stumps, logs, shrubs, brush and vegetation and other items that would interfere with construction operations. Remove stumps entirely. Grub out matted roots and roots over 75 mm 3 inches in diameter to at least 500 mm 18 inches below existing surface. Remove all organics and rocks greater than 25 mm 1 inch from the top 150 mm 6 inches.

3.1.3 Grading

Grade subgrade to the lines and grades indicated on the plans. Provide finished surface that are uniformly graded and free from depressions, mounds, or windrows. The top surface of the subgrade must be between 0 and minus 76 mm 3 inches of the grades indicated on the plans. No plus tolerance will be permitted.

3.1.4 Subgrade Compaction

Subgrade materials that exhibit deflection greater than 25 mm 1 inch or rutting during proof rolling need to be scarified, aerated, and re-compacted to 90 percent of maximum dry density based on ASTM D1557 or

95 percent of maximum dry density based on ASTM D698 at [plus][0-4][_____] percent of optimum moisture content prior to being considered for remedial action by the Contracting Officer.

3.1.5 Proof Rolling

Perform proof rolling on exposed subgrade that is unfrozen and free of surface water (wet conditions resulting from rainfall).[Notify the Contracting Officer a minimum of three business days prior to proof rolling.][Perform proof rolling in the presence of the Contracting Officer.][After final grading to the planned elevation,] proof roll the existing subgrade of all areas to receive compacted clay barrier layer with six passes of a[[45][_____] metric ton [50][_____] short ton loaded offroad dump truck] [[45][_____] metric ton[50][_____] short ton loaded scraper]. Operate the [scraper][truck] in a systematic manner to ensure the number of passes over all areas, and at speeds between 4 to 5.5 km 2.5 to 3.5 miles per hour. The subgrade is considered to extend 1.5 meters 5 feet beyond the limits of the clay barrier layer. Smooth drum roll the final subgrade surface with a smooth drum compactor.

3.2 INSTALLATION

3.2.1 Material Handling Plan

Submit a Material Handling Plan at least [15][_____] business days prior to clay placement. Do not place clay until the Material Handling Plan is approved. Include the following in the plan: processing and placement of the clay; type, model number, weight and critical dimensions of equipment to be used for soil processing, compaction, scarification, and smooth rolling; method of protecting clay from changes in moisture content and freezing after placement.

3.2.2 Pre-Processing

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NOTE: Clods of soil can be broken down with tilling equipment. Stones can be sieved out of the soil with large vibratory sieves, mechanized "rock pickers" passed over a loose lift of soil, or by laborers who remove oversized material by hand. Pulverization machines can process soil in a loose lift, breaking down hard chunks and crushing stone or large clods.

****

Prior to placement of the clay barrier layer, process clay to break down clods of soil to less than 50 mm 2 inches, to remove rocks greater than the maximum particle size specified in paragraph CLAY, and condition the soil to the proper moisture content for compaction. Process clay at the location designated on the drawings or approved by the Contracting Officer. The Materials Handling Plan must identify equipment and methods to process the soil in preparation of placement.

3.2.3 Clay Placement

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NOTE: Clay is placed parallel to the direction of maximum slope. Clay placement parallel to the slope becomes difficult on slopes steeper than 3

horizontal on 1 vertical. Horizontal lifts should be considered for clay placement on slopes steeper than 3 horizontal on 1 vertical.

The U.S. Environmental Protection Agency document, EPA/600/R-93/182 Quality Assurance and Quality Control for Waste Containment Facilities discourages the use of grade stakes which penetrate the clay barrier layer to control lift thickness.

If a test pad is considered necessary, include Section 02 66 16 TEST FILL in the project specifications and provide a reference in this section. Section 02 66 16 TEST FILL should be modified to include hydraulic conductivity testing per ASTM D6391.

****

Place clay to the lines and grades shown on the drawings. The thickness of the clay liner at any location must be measured perpendicular to the slope at that location. Place the clay in loose lifts not to exceed 25 mm 1 inch less than the foot length of the compactor. Do not place subsequent lifts until the previous lift has passed all testing requirements described in paragraph FIELD QUALITY CONTROL. In areas where hand operated tampers must be used, the loose lift thickness exceeding [100][_____] mm [4][_____] inches is not acceptable.[Do not drive grade stakes into the clay barrier layer.][If grade stakes are driven into the clay barrier layer to control lift thickness, number and account for them at the end of each shift. When removing grade stakes, do not leave broken portions of the grade stakes in the clay barrier layer. Backfill and compact holes left by grade stakes by following the procedure in paragraph Repair of Voids.]

For clay barrier layers placed over geosynthetics, the first lift must be 305 mm 12 inches. This lift is not considered in determining the required thickness of the clay barrier layer. For clay barrier layers placed above geosynthetics, require the placement and compaction equipment work from the base of the slope up to prevent damage to underlying geosynthetics. Do not operate equipment directly on the top surface of geosynthetics.

3.2.4 Moisture Control

Place and compact clay within the "Acceptable Zone" moisture content range in the approved Borrow Source Assessment Report. Maintain uniform moisture content throughout each lift. Add and thoroughly incorporate water into the clay to ensure uniformity of moisture content prior to compaction. Seal roll the clay barrier layer with approved steel wheeled rollers and make smooth and free from ruts or indentations at the end of every working day, when precipitation is forecast, or at the completion of compaction operations in an area.

3.2.5 Compaction

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NOTE: Special compaction procedures are required if geosynthetic layers are located immediately beneath the clay barrier layer. This lift of soil is typically placed with low ground pressure track mounted equipment with a track pressure of 21 to 41

kPa 3 to 6 psi.

****

Compact clay to meet the density requirements in the approved Borrow Source Assessment Report and by at least [six][_____] one-way passes of the approved compaction equipment over all areas of each lift. Compactor wheel passes must have 15 percent to 25 percent overlap to assure compaction over the entire area. For self-propelled compactors, one pass is defined as one pass of the entire vehicle. Use hand operated tampers in areas where standard compaction equipment cannot be operated.

The transition from an existing full-depth section of clay barrier layer to the beginning of an adjacent section that is to be constructed subsequently must be accomplished by cutting minimum 3 meter 10 foot wide stair steps for each lift of the clay barrier layer, scarifying the surface of each stair step, and then immediately placing the adjacent lifts of clay liner.

3.2.6 Scarification

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NOTE: For geomembrane/clay composites, the final lift of clay is smooth rolled instead of being scarified to allow intimate contact between the clay surface and the overlying geomembrane. Smooth rolling also helps to prevent desiccation and precipitation infiltration increasing moisture outside of the workable range during delays in construction.

****

Prior to placement of the next lift, perform scarification on all areas of the upper surface of each clay lift that has been seal rolled. Accomplish scarification with approved equipment. If a geosynthetic is to be placed in contact with the clay surface, do not scarify the final lift of clay. Roll the final lift with the approved smooth steel wheeled roller to provide a smooth surface with no ridges or depressions.

3.2.7 Repair of Voids

Repair voids created in the clay barrier layer during construction (including, but not limited to, penetrations for test samples, grade stakes, and other penetrations necessary for construction) by removing sand or other non-clay material, placing clay backfill in lifts no thicker than 76 mm 3 inches and tamping each lift with a steel rod. Tamp each lift a minimum of 25 times altering the location of the rod within the void for each blow. Scarify, fill and compact to grade other ruts and depressions in the surface of the lift.

3.2.8 Construction Tolerances

Provide finished surfaces that are uniformly graded and free from depressions, mounds, or windrows. The top surface of the clay barrier layer greater than [76][_____] mm [3][_____] inches above the lines and grades shown on the drawings is prohibited. No minus tolerance will be permitted.

3.3 FIELD QUALITY CONTROL

3.3.1 Clay Material Laboratory and Field Test Results

During construction of the clay barrier layer, take representative samples for testing at the frequencies listed in Table 3 [from the borrow source][from onsite stockpiles][after a loose lift of clay has been placed][_____]. Test results must meet the requirements listed in Table 1.

TABLE 3 - CLAY MATERIAL PROPERTIES

Property	Frequency	Test Method
Particle size analysis (Note 1)	[800][_____] cubic meters [1,000][_____] cubic yards	ASTM D6913/D6913M
Percent Passing 0.075 mm (No. 200 sieve)	[800][_____] cubic meters [1,000][_____] cubic yards	ASTM D1140
Liquid Limit (Note 1)	[800][_____] cubic meters [1,000][_____] cubic yards	ASTM D4318
Plastic Limit (Note 1)	[800][_____] cubic meters [1,000][_____] cubic yards	ASTM D4318
Plasticity Index (Note 1)	[800][_____] cubic meters [1,000][_____] cubic yards	ASTM D4318
Compaction (Note 2)	[5,000][_____] cubic meters [6,500][_____] cubic yards	ASTM D698 ASTM D1557

Note 1: Perform at least one test each day that soil is placed.
Note 2: Compare compaction test results to previous results on the same material type to verify the compaction characteristics have remained the same.

3.3.2 Moisture Content and Density Tests of Clay

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NOTE: Test results using ASTM D6938 may show a significant amount of scatter in some situations. ASTM D4643 (microwave method) can be used as an alternative to ASTM D6938 for quick determinations of moisture content.
****

Perform moisture content and density tests, for clay in-place, in a grid pattern staggered for successive lifts, so that sampling points are not at the same location in each lift. These tests are needed to assure hydraulic conductivity is within acceptable zone and meets specifications. Perform moisture content and density tests in accordance with Table 4.

TABLE 4 MOISTURE CONTENT AND DENSITY TESTS OF IN-PLACE CLAY		
Property	Frequency Per Lift	Test Method
Nuclear Moisture Content	[450][_____] square meters [5000][_____] square feet - Minimum of 3 tests per day	ASTM D6938
Standard Moisture Content	1 for every 10 nuclear tests, minimum 1 test per day	ASTM D2216
Nuclear Density	[450][_____] square meters [5000][_____] square feet - Minimum of 3 tests per day	ASTM D6938
Standard Density	1 for every 20 nuclear density tests, minimum 1 test per day	ASTM D1556/D1556M or ASTM D2167

3.3.2.1 Test Frequencies and Locations

Perform nuclear density and moisture content tests at locations that are representative of moisture and compaction based on visual observations during placement of the lift. Perform standard tests at locations which are underneath the nuclear gauge or as close as possible to the location of the nuclear tests being checked.

3.3.2.2 Nuclear Density and Moisture Content Tests

Take nuclear density readings in the direct transmission mode. When ASTM D6938 is used, check and adjust calibration curves using only the sand cone method as described in ASTM D1556/D1556M. ASTM D6938 results in a wet unit weight of soil and when using this method, use ASTM D6938 to determine the moisture content of the soil. Check calibration curves furnished with the moisture gauges along with density calibration checks as described in ASTM D6938; make calibration checks of both the density and moisture gauges at the beginning of a job on each different type of material encountered and at intervals as directed by the Contracting Officer.

3.3.2.3 Test Results

Plot the field moisture content and density test results on the "Acceptable Zone" plot that corresponds to the appropriate material type being tested. If test results are not within the "Acceptable Zone" for moisture content or density, repair the lift of soil out to the limits defined by the Qualified Technician based on visual observation, process monitoring, and additional nuclear testing. Retest the area as directed. Document repairs to the clay barrier layer including location and volume of soil affected, corrective action taken, and results of retests.

3.3.3 Hydraulic Conductivity Tests of Clay

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NOTE: Laboratory hydraulic conductivity tests during clay barrier layer installation constitute a major inconvenience because the tests usually take several days to perform. For this reason, the use of laboratory hydraulic conductivity tests should be

minimized or eliminated if possible.
****

Take undisturbed samples from the in-place clay for hydraulic conductivity testing at a frequency of once per 3,720 square meter 40,000 square feet for each lift of clay placed. Cut samples from the lift in accordance with ASTM D1587/D1587M and transport in the vertical position in accordance with ASTM D4220/D4220M, Group C. Test each undisturbed sample for hydraulic conductivity in accordance with ASTM D5084[, moisture content in accordance with ASTM D2216,][particle size analysis in accordance with ASTM D6913/D6913M,][and][liquid and plastic limits in accordance with ASTM D4318]. Conduct hydraulic conductivity testing in accordance with paragraph HYDRAULIC CONDUCTIVITY TESTING. If any test result is greater than the "Maximum Allowable Hydraulic Conductivity", modifications must be proposed and approved for future placement of clay of that type. If the hydraulic conductivity of any test is more than one-half of one order of magnitude greater than the "Maximum Allowable Hydraulic Conductivity", perform [three][_____] additional tests near the location of the original failed test. If all retests pass, take no additional action. If any of the retests fail, repair the area out to the limits defined by passing hydraulic conductivity tests. Retest the area as directed. Document repairs to the clay barrier layer including location and volume of soil affected, corrective action taken, and results of retests.

3.3.4 Government Quality Assurance Testing

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NOTE: Quality assurance (QA) testing and inspections should be performed on all landfill construction as the liability is long term and cost due to failure is significant. Factors to consider include whether the Government has access to a laboratory that can analyze quality assurance samples in a timely manner to not delay the project execution. If conducting quality assurance testing, a separate third-party quality assurance contract should be considered based on the qualifications of the Government QA personnel, the size and importance of the project, and the impacts of clay barrier layer failure.

Use of quality assurance testing data also needs to be considered. A relatively straightforward data use is to compare quality assurance sample results to the project performance requirements, and failing result would be treated the same way as a failing Contractor test result. A more complicated data use is to compare results from quality assurance samples and contractor quality control samples for the purpose of determining if there is meaningful disagreement between the results. In this case, procedures would need to be developed for determining when there is a meaningful disagreement between quality assurance and quality control sample results; corrective actions for when a meaningful disagreement was identified would also need to be developed. The process of defining procedures for identifying and correcting meaningful differences

should be documented in a project specific CQA Plan or Quality Assurance Project Plan and referenced in this specification; the process is likely too complex to be adequately defined in this specification.

Two options are provided for defining Government Quality Assurance. The first option is to defer details of the Government QA to a separate CQA Plan. The CQA Plan would need to be developed and provided to the Contractor with the project specifications. This option would be preferred for large, complex projects where the clay barrier layer is one component of a larger waste containment system. A second, simpler option is provided to define Government QA testing frequency.

The Government's QA personnel should visit off-site borrow sources to assure that soils identified in the Borrow Source Assessment Report are being utilized and no water is being added.

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[Work will be monitored and tested in accordance with the CQA Plan. Be aware of all monitoring and testing activities defined in the CQA Plan and account for these activities in the construction schedule. Quality Assurance testing and monitoring does not relieve the Contractor of the responsibility to complete the quality control testing and monitoring defined in this specification Section.]

[

[Provide][The Contracting Officer will provide] duplicate quality assurance samples to the Government's quality assurance laboratory at a frequency of one set of samples per [10][_____] sets of quality control tests performed. Quality assurance samples will be tested for the same parameters as the parent quality control sample. A failed quality assurance test will require the same corrective actions defined in this Section as a failed Contractor quality control test. The Contracting Officer may require additional quality assurance tests as a result of failed quality assurance or quality control tests. Account for Government quality assurance testing in the construction schedule. Quality Assurance testing and monitoring does not relieve the Contractor of the responsibility to complete the quality control testing and monitoring defined in this specification Section.]

3.4 PROTECTION

3.4.1 Moisture Content

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NOTE: Smooth rolling or other measures as defined in the Material Handling Plan are necessary to limit moisture loss and/or promote run-off of surface water.

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After placement, maintain or adjust moisture content per the procedure defined in the Material Handling Plan to meet the acceptable zone criteria.

3.4.2 Erosion

Repair all visible erosion, including but not limited to erosion rills greater than 13 cm 0.5 inch depth that occurs in the clay barrier layer and re-establish grades.

3.4.3 Freezing and Desiccation

Prevent freezing and desiccation of the clay barrier layer. If freezing or desiccation (soils outside the acceptable moisture window, cracking, or platelet failure) occurs, remove or recondition the affected soil as directed.

3.4.4 Retests

Retest areas that have been repaired as directed. Document repairs to the clay barrier layer including location and volume of soil affected, corrective action taken, and results of retests.

-- End of Section --