Section 8: Facility Construction Program

8.1 Introduction

Objective

The objective of the construction program is to translate the Department-approved engineering design into a completed facility that meets or exceeds the design plan specifications and performance objectives.

Elements

The facility construction program should include the following elements:

- an organized, qualified construction project team
- Department-approved design drawings and specifications for each phase of landfill development
- a Construction Quality Control (CQC) program
- a Construction Quality Assurance (CQA) program, and
- Construction Certification Reports based on an evaluation of CQC and CQA documentation which certify that construction was completed in accordance with Department-approved plans and specifications

How to respond

Submit the information below to the Department for each phase of landfill development (i.e., construction of new cells, cell closure, or environmental control facilities).

Document	When to submit
CQA plan	prior to initiating construction
soil liner test pad evaluation report	prior to beginning construction of the soil liner
construction certification report	after completing each phase of construction

Reference: OAR 340-93-140 and OAR 340-93-150 provide information on construction documents

In this section

This section describes the major construction project elements, including:

- construction project team
- construction guidelines
  - soil test pad
  - soil liner
  - excavation and subgrade preparation
  - geosynthetic liners
  - leachate and gas collection systems
- quality control program
- quality assurance plan
- construction certification reports

Differences in materials

The physical properties of natural earth materials are generally more variable than the properties of manufactured materials (e.g., geomembranes) which are produced under factory controlled conditions. Accordingly, these guidelines concentrate more on methods for earth-materials construction.

8.2 Construction Project Team

Project team organization

Organize the project team in terms of "Owner", "Designer", and "Constructor" or other equivalent divisions of responsibility. Regardless of the contractual arrangement used, the Owner, Designer, and Constructor functions are discrete, independent responsibilities.

Establishing the team

Establish and document the construction project team organization, including:

- a list of key project team members and their roles and responsibilities
- the minimum required experience for each project team member
- key project team members, their qualifications, and phone numbers and addresses
- an organizational flow chart identifying members of the project team, lines of authority, and lines of communication between the various team members

Team roles

The table below shows a typical construction project team.

Team Member	Role
Project Manager	Individual who represents the owner and is responsible for the overall coordination and management of the project activities
Owner	Party who initiates the project and is responsible for establishing and directing the project to completion
Owner's Team	Persons who advise and assist the owner in specialized areas and, if applicable, person(s) to whom the owner delegates authority to act on the owner's behalf
Construction Quality Assurance (CQA) Consultant	Party(s), who is part of the Owner's Team, and independent from the Project Manager, Constructor and Manufacturer. The CQA Consultant is responsible for observing, conducting and documenting activities related to the quality assurance of materials and construction on behalf of the Owner
Designer	Party whose primary role is to conceive, plan and provide quality design solutions in response to the owner's stated requirements
Design Team	Experienced staff and subcontractors who are responsible for various aspects of the design

Team Member	Role
Constructor	May be a contractor. Party responsible for planning, managing, and accomplishing the construction activities
Construction Team	Construction staff, material and equipment suppliers, specialty sub-contractors assembled by the Constructor

Note: For smaller projects, multiple functions can be accomplished by a single individual

Basis for organization

"Successful construction projects are conceived, planned, designed, and built by a project team consisting of an owner, design professional, and constructor. Quality is achieved when each team member's obligations are fulfilled competently and in a timely fashion, in cooperation with the other members." (ASCE Manual No. 73.)

8.3 Construction Guidelines - Soil Test Pad

Purpose of soil test pad

The purpose of a test pad(s) is to model the construction of the full-scale liner to verify that proposed construction materials and methods will produce the desired compaction and in-situ hydraulic conductivity. The assessment will enable the Project Team to establish final requirements for soil processing, placement and compaction.

Requiring a test pad

The design specifications should require the Constructor to complete a successful test pad evaluation before constructing the full-scale soil liner. An additional test pad should be prepared and evaluated for each significant change in construction materials, equipment, or methodology.

Construction procedures

Construct soil test pads according to the table below.

Step	Action
1	Use the same soil material, CQC program, and construction equipment and methods that will be used for the full-scale liner
2	Classify representative soil samples according to the Unified Soil Classification System (ASTM D2487)
3	Evaluate soil samples to define an acceptable range of water content and dry unit weight. Use careful judgment in interpreting laboratory hydraulic conductivity values, (i.e., there may be up to 1 order-of-magnitude difference between laboratory and field values) Reference: Daniel, D. E., and Benson, C. H. (1990), "Water Content - Density Criteria for Compacted Soil Liners," *Journal of Geotechnical Engineering*, Vol. 116, No. 12, pp. 1811 -1830.
4	Construct the test pad at least four times the width of the widest piece of equipment to be used
5	Construct the test pad long enough to allow the compaction equipment to attain normal operating speed before reaching the test area
6	Construct at least four compacted lifts

Achieving low hydraulic conductivity

The most important factors in achieving hydraulic conductivity criteria are:

- using suitable soil materials
- using appropriate construction equipment
- placing the soil at the correct water content
- properly preparing the surface between lifts
- achieving density specifications by using appropriate compaction equipment and procedures, and
- protecting completed lifts from damage

Duties of CQA consultant

Suggested duties of the Construction Quality Assurance (CQA) consultant include:

- Observe, approve and document the suitability of the prepared subgrade
- Observe, approve and document soil material selected for construction
- Observe and record during soil placement and compaction:
  - weather conditions
  - the construction equipment and methods used (e.g., equipment type and specifications, lift thickness before and after compaction, number of compactor passes, compactor speed), and
  - the CQC program
- Test the physical properties that will be used to evaluate construction of the full-scale soil barrier, including at least four water content (ASTM D2216) and four density (ASTM D1556) tests per compacted lift
- Collect at least four undisturbed samples from each compacted lift immediately adjacent to where physical properties are tested, and from those samples obtain at least four undisturbed test specimens from varying depths in the compacted lift. Test the specimens in the laboratory for hydraulic conductivity (ASTM D5084) to determine any correlation between laboratory hydraulic conductivity, tested physical properties, and in-situ hydraulic conductivity
- Repair or observe the repair of all holes left by density testing and soil sample collection
- Conduct field tests to determine in-situ hydraulic conductivity. The Department recommends at least one sealed double ring infiltrometer test (ASTM D5093 or equivalent method)
- Dig at least four (4) test pits in the test area, inspect for evidence of voids, large pores between remnant clods, signs of poor bonding between lifts, and other visible problems, and
- Prepare a report documenting the test pad(s) evaluation

Test pad evaluation report

The CQA consultant should prepare and submit to the Department a soil liner test pad evaluation report that includes:

- a summary of test data
- data analysis
- conclusions and recommendations regarding test pad performance and full-scale soil barrier construction.
- a detailed description of the construction materials, equipment and methods to be employed for full-scale liner construction

---

Report review procedures

The Project Manager and Designer should evaluate the CQA Consultant's report and the test pad's conformance to the design specifications.

If the test pad's performance	then
conforms to design specifications	construct the full-scale soil liner using the same construction methods, equipment, and materials
fails design specifications	require the Constructor to construct and evaluate another test barrier using modified construction material, equipment, and methods

---

Alternative to test pad assessment

The project schedule may not allow time to complete the test pad evaluation before the soil liner is constructed. If this situation arises, demonstrate to the Department that a full evaluation of the test pad is not needed to verify that the liner will meet the specifications.

Demonstration content

The demonstration should:

- show, with laboratory testing, that the proposed soil-liner material easily meets the specified hydraulic conductivity
- permit Department representatives to observe construction of the test pad and excavation of test pits
- show that the lifts are adequately bonded together and that soil clods are adequately remolded (few inter-clod voids or macro-pores should be visible)
- use the same materials, methods, and equipment to construct the soil liner, and
- recognize that completed liner segments may need re-construction or modifications if the soil test pad fails to meet the design specifications

---

8.4 Construction Guidelines -- Soil Liner

Test pad results

The Project Manager and Designer should use the test pad modeling results to establish final requirements for liner construction and performance (specified compaction and hydraulic conductivity criteria).

Factors in establishing final construction requirements

In establishing final construction requirements, the Project Manager and Designer should carefully consider the following construction variables:

- properties of the low-permeability soils to be used for liner construction
- method of excavating and processing the soil prior to placement
- pre-compaction thickness and conditioning methods (e.g., disking, pulverizing, moisture adjustment)
- compaction equipment type, weight and length of feet (for footed rollers)
- compactor operations (number of compactor passes and maximum compactor speed)
- protection of compacted lifts that may be exposed to the elements
- scarification and moisture control between lifts
- mixing of bentonite and other soil additives

Key construction elements

Establish a construction program that has the following elements:

- systematic construction quality control (CQC) such that the resulting liner meets or exceeds the test pad's performance
- a CQA Consultant to monitor the construction and ensure that completed soil liners meet or exceed specifications, and
- provisions to protect completed soil liners from the effects of weather and other construction activities

Modifications to construction specifications

As the Constructor and CQA Consultant gain construction experience and "get a feel" for the soils, it may become desirable to modify certain construction criteria. Such adjustments should be made as described in the table below.

If the modification is	then	Examples
“functionally inferior”	obtain Department authorization prior to implementation	modifications including less compactive effort, reduced quality control, and increased lift thicknesses that potentially result in diminished hydraulic and strength properties
“functionally superior”	continue with construction	modifications, such as increased compactive effort, increased quality control, thinner lift thicknesses, that potentially reduce the hydraulic conductivity and enhance strength properties

8.5 Construction Guidelines -- Excavation and Subgrade Preparation

Excavation, stockpiling, and processing

Perform earthwork activities in accordance with the table below.

Step	Action
1	Segregate excavated soils according to their properties
2	Process excavated soils as necessary to meet required material specifications (e.g., pulverizing the soil to break down clods or screening the soil to remove large particles)
3	Place excavated/processed soils into compatible stockpiles of uniform material
4	Provide erosion control measures for excavation and stockpiling activities
5	Adjust the moisture content as necessary before using excavated or stockpiled soils (i.e., water needs to penetrate clods so they can be remolded)

Subgrade preparation

Construction procedures for liner or cover system subgrades should address the following factors:

- control of differential settlement
- removal of soft spots
- quality control testing (density, moisture content, soil classification, soil gradation)

8.6 Construction Guidelines -- Geosynthetic Materials

Typical geosynthetic materials

Landfill construction typically involves many applications for geosynthetic materials, including:

- geomembranes in liners and covers
- geotextiles as filters, cushions, and soil separators
- geogrids for slope and foundation support, and
- drain-nets for drainage

Installation specifications

Install geosynthetic materials in conformance with the specifications for:

- function and desired properties
- minimum testing and acceptance
- testing and acceptance procedures
- damage prevention, and
- installation procedures

Testing and acceptance procedures

Establish conformance testing and acceptance requirements that include the following procedures:

- The Constructor or Manufacturer should provide the Project Manager the Manufacturer's quality control certification (i.e., verification that the geosynthetic material meets project specifications)
- The Constructor or Manufacturer of a geomembrane should provide quality control certificates issued by the resin supplier, quality control certificates for each roll produced and certification that the supplied geomembrane and extrudate have the same material properties, and
- The Constructor or CQA Consultant should conduct sampling and conformance testing in accordance with ASTM D4759 "Standard Practice for Determining the Specification Conformance of Geosynthetics" to verify the manufacturer's certification

Damage prevention

Prevent damage to the geosynthetic material by using appropriate techniques for delivery packaging, labeling, transportation, handling and storage.

Installation procedure

Install the geosynthetic material as the specifications prescribe for:

- site preparation prior to placement of geosynthetic
- geosynthetics handling, placing, anchoring, seam overlaps, and post-installation inspection
- geomembrane seam welding (including preparation of geomembrane sheets and seaming equipment), weather and temperature constraints for seaming
- geomembrane wrinkles, folds, and bridging
- seam quality control testing and inspection
- repairing inadequate seams and damaged geomembranes, and
- covering or otherwise protecting geomembranes after installation to prevent damage

8.7 Construction Guidelines -- Leachate and Gas Systems

Leachate system construction

Construct the primary and secondary leachate collection and removal system(s) (LCRSs) according to specified requirements for:

- the performance objectives for each system component (i.e., for granular drainage material the hydraulic conductivity to be achieved)
- desired material properties (e.g., hydraulic conductivity, grain size distribution, non-carbonate rock for granular drainage material or inside diameter for LCRS piping)
- the required thickness for granular drainage and filter layers, and
- constructor requirements for LCRS work execution including:
  - slopes allowances to compensate for projected differential settlement
  - protection of liners during placement of overlying granular drainage materials
  - pre-operational cleaning and maintenance of the LCRS, and
  - demonstrating LCRS pipe continuity (e.g., pull a ball or other uniform object through the pipes)

Gas system construction

Construct the landfill gas control system according to the specified requirements for:

- construction staging and coordination with landfill operation and development
- connection of system components to and penetrations through geomembrane covers and other geosynthetics
- safety precautions for the Constructor's field crews and others who may be exposed (directly or indirectly) to landfill gas
- gas production and control system performance, and
- operational objectives

8.8 Quality Control Program

CQC defined

Construction quality control (CQC) refers to those actions taken by Manufacturers, Fabricators, or the Constructor to confirm that products and work quality meet the requirements of the contract. CQC includes inspections and testing of all furnished, constructed, and installed components. These activities are independent of construction quality assurance (CQA) activities.

CQC program

Establish detailed construction quality control (CQC) requirements for materials and workmanship, to show the Constructor how to furnish products and execute work. CQC should include systematic inspections and measures to control the quality of construction and to ensure conformance with the project specifications and contract requirements.

8.9 Quality Assurance Plan

CQA plan

Prepare a detailed construction quality assurance (CQA) plan that verifies and documents proper construction of facility components. The CQA plan should describe the proposed measures for monitoring the quality of materials and work performance. CQA plan elements pertaining to foundations, subgrades, embankments, soil barriers, geosynthetics, LCRSs, and landfill gas control systems should be developed and administered by a Professional Engineer with current Oregon registration and experience in the technical area.

CQA defined

CQA is an overview and inspection program consisting of systematic observations and tests to ensure that the final product meets design specifications. CQA plans, design plans and specifications, observations, and tests are used to provide quantitative criteria for evaluating final product acceptability.

Plan contents

The CQA plan should include site-specific information on the following topics:

- staff roles, responsibility, authority and communication
- qualifications of CQA consultant
- qualifications of construction team
- inspection activities
- geosynthetic construction
- earthwork construction
- documentation

Roles and responsibilities

The CQA plan should describe the role, responsibility, and authority of each party involved in executing the CQA plan. The plan should include an organizational flow diagram outlining the management structure, lines of communication, chain-of-command, and implementation procedures.

Qualifications of CQA consultant

The CQA plan should describe the technical expertise of the CQA consultant. The CQA consultant should represent the Owner's interests as an independent, qualified party and is responsible for observing, evaluating, and documenting quality of materials and construction.

Qualifications of construction team

The CQA plan should establish minimum qualifications for earthwork contractors, geosynthetic installers and geosynthetic material manufacturers.

Inspection activities

The CQA plan should outline the observations and tests that will be used to evaluate conformance with all design criteria, plans, and specifications for each project component.

Geosynthetic construction

The CQA plan should describe the responsibilities of the CQA consultant. Suggested duties include:

- monitoring geosynthetic material delivery, unloading and on-site storage and transport
- selecting geosynthetic material (destructive samples) for conformance testing
- determining the acceptability of geosynthetics according to ASTM D4759 "Standard Practice for Determining the Specification Conformance of Geosynthetics"
- monitoring the deployment of geosynthetics
- monitoring geosynthetic seaming operations
- monitoring and documenting CQC testing procedures (i.e., non-destructive seam testing, field tensiometer testing)
- monitoring and documenting geomembrane CQA testing (i.e., destructive seam sampling and testing, repair operations, sample labeling)
- documenting any on-site activities that could result in damage to the geosynthetics
- maintaining appropriate lines of communication with other project team members as specified in the CQA plan

---

Earthwork construction

The CQA plan should describe procedures associated with earthwork, including:

- grading
- foundations
- embankments
- soil liners and covers
- granular drainage and filter layers
- excavations and backfill
- top soil (vegetative) layers
- road building, and
- soil processing (e.g., mixing with bentonite)

CQA of earthwork

CQA activities should include:

- earthwork monitoring
- earthwork sampling and testing
- evaluating prospective liner materials, and
- evaluating constructed soil liners

Earthwork monitoring

The CQA consultant should oversee all key phases of earthwork to monitor and document that materials and procedures meet the design specifications. The CQA consultant's oversight should include:

- borrow soils properties and performance
- test pad construction and performance
- borrow soils stockpiling methods
- raw material processing
- foundation and sub-grade preparation
- soil layer thickness and protection of underlying layers
- repair of any holes (e.g., from grade stakes) or other construction-related damage
- soil-liner construction (soil density, moisture content, permeability, equivalency to test pad construction)
- identification and repair of penetrations of the soil liner (e.g., penetrations resulting from CQC/CQA testing)
- protection of completed soil liner sections
- all other earthwork components (i.e., granular drainage or gas venting layers, operations layer, protective layers and topsoil layer)
- identification and modification of activities that could damage liners or drainage layers

---

Earthwork sampling and testing

The CQA plan should describe sampling parameters and procedures for each discrete earthwork activity including testing frequency, rationale for selecting test locations, and acceptance and rejection criteria.

The QA Consultant should observe all aspects of earthwork, and personally perform the soil sampling and testing to develop a "feel" for the material. This hands-on involvement may improve the QA Consultant's observational skills and judgment, ultimately translating into better quality assurance.

Evaluating prospective liner materials

The CQA plan should specify parameters and testing frequencies for evaluating soils intended for liner construction. Test samples obtained from the borrow area, processing area, stockpile area or final placement area, provided:

- the samples meet low-permeability specifications, and
- the soil is suitable for or can be conditioned for compaction

Liner soil testing

The table below lists recommended parameters and testing frequencies for evaluating prospective soil liner material.

Parameter being tested	Test method reference	Testing frequency	Recommended performance
Percent fines (passing a No. 200 sieve)	ASTM D1140	1 per 1000 cy and 1 test each day soil is excavated or placed	$\geq$ 50%
Percent gravel (dry-weight retained on the No. 4 sieve)	ASTM D422	1 per 1000 cy and 1 test each day soil is excavated or placed	$\leq$ 10%
Atterberg limits	ASTM D4318	1 per 1000 cy and 1 test each day soil is excavated or placed	Plasticity Index $\geq$ 10%
Water content	ASTM D3017 ASTM D4643 ASTM D2216 (at least every 5th sample)	1 per 1000 cy and 1 test each day soil is excavated or placed	-----
Moisture/Density/ Permeability relationships	ASTM D698 ASTM D1557 ASTM D5084	1 per material type	

Note: Other equivalent tests may be used

Reference: Use relationships to define an acceptable range of Water Content and Dry Density Unit Weight, in accordance with procedures described by Daniel, and Benson, C. H. (1990), "Water Content - Density Criteria for Compacted Soil Liners," Journal of Geotechnical Engineering, Vol. 116, No. 12, pp. 1811 - 1830.

Evaluating the constructed soil liner

The CQA plan should specify parameters and testing frequencies for evaluating compacted soil liners. The plan should allow testing frequencies to be increased at the discretion of the CQA consultant.

Recommended parameters and frequencies

The table below lists recommended parameters and testing frequencies for evaluating constructed soil liners.

Parameter being tested	Test method reference	Testing frequency	Recommended performance

Water content	ASTM D3017 ASTM D4643 ASTM D2216(at least every 5th sample)	5/acre/compacted lift	
Density	ASTM D2922 ASTM D1556(at least every tenth sample)	5/acre/compacted lift	Nuclear density test should measure soil density near the bottom of each compacted lift; calibrate nuclear gauges to a known density each day of use
Thickness	Elevation monitoring	50 feet center to center or minimum 6 points per grade at top of first compacted lift and top of completed soil liner	

Note: Other equivalent tests may be used

Documentation

The CQA plan should specify detailed reporting requirements for the CQA activities, including:

- daily record keeping (observation and test data sheets)
- problem reporting and corrective measures data sheets
- project Manager and Designer acceptance reports (for errors, inconsistencies, and other problems)
- final documentation including as-built drawings, and
- the signature or initials of the person maintaining the records and generating the reports

8.10 Construction Certification Reports

Submittal

Construction Certification Reports must be submitted to the Department each time a landfill development phase is completed and/or before a newly constructed waste management unit (a landfill cell or leachate impoundment) is activated. The report should document and certify that all required components and structures have been constructed in compliance with the permit requirements and approved design specifications.

Reference: OAR 340-93-150

Report content

Construction certification reports should include the following elements:

- an executive summary describing how well the project went and major problems encountered
- a summary of all construction and CQA activities
- a summary of all CQA observations, daily inspection/photo/video logs, and test data sheets
- problem identification/corrective measures
- designer's acceptance reports for errors and inconsistencies
- deviations from design and material specifications, including justifying documentation, and copies of change orders and recorded field adjustments
- certificates of acceptance (e.g., acceptance of subgrade for geomembrane liner installation)
- as-built drawings and photographs, including record surveys of soil liner and granular drainage layer thicknesses
- a certification statement(s) and signatures legally representing the CQA Consultant, Designer and Owner, one of the which is that of a professional engineer registered in Oregon, and
- a copy of the notation on the deed to the facility property for all closed cells, as required by 40 CFR 258.60(i)

8.11 Additional Resources

Low-permeability soil liner	Daniel, D. E. (1987), "Earthen Liners For Land Disposal Facilities," Geotechnical Practice for Waste Disposal '87 Proceedings, ASCE, Geotechnical Special Publication No. 13., pp. 21-39; Daniel, D. E., and Benson, C. H. (1990), "Water Content - Density Criteria for Compacted Soil Liners," Journal of Geotechnical Engineering, Vol. 116, No. 12, pp. 1811 - 1830; U.S. EPA (1988), Design, Construction, and Evaluation of Clay Liners for Waste Management Facilities, EPA/530/SW-86/007F; U.S. EPA (1988), Lining of Waste Containment and Other Impoundment Facilities, EPA/600/2-88/052, Chapter 9; and U.S. EPA (1989), Seminar Publication: Requirements for Hazardous Waste Landfill Design, Construction, and Closure, EPA/625/4-89/022, Chapter 6.
Geosynthetics -- construction quality control	U.S. EPA (1988), Lining of Waste Containment and Other Impoundment Facilities, EPA/600/2-88/052, Chapter 9; and. U.S. EPA (1989), Seminar Publication: Requirements for Hazardous Waste Landfill Design, Construction, and Closure, EPA/625/4-89/022, Chapter 6. For guidance on seaming geomembranes: U.S. EPA (1991), Technical Guidance Document: Inspection Techniques for the Fabrication of Geomembrane Field Seams, EPA/530/SW-91/051.
Leachate Collection and Removal	U.S. EPA (1988), Lining of Waste Containment and Other Impoundment Facilities, EPA/600/2-88/052, Chapter 9.

Construction Quality Assurance

U.S. EPA (1988), Lining of Waste Containment and Other Impoundment Facilities, EPA/600/2-88/052, Chapter 10;

U.S. EPA (1985), Construction Quality Assurance for Hazardous Waste Land Disposal Facilities, Public Comment Draft, EPA/530-SW-85-021;

Daniel, D. E., "Summary Review of Construction Quality Control for Compacted Soil Liners," Waste Containment Systems: Construction, Regulation, and Performance, R. Bonaparte (ed.), ASCE, New York, pp. 175 - 189; and

Chemical Waste Management, Inc. (June 15, 1990), Quality Assurance Manual For The Installation Of Geosynthetic Lining Systems.

General reference

For further information on construction principles and procedures, and project organization see ASCE (1990), Quality in the Constructed Project, ASCE Manual No. 73.
