

DER-17: Guidelines for Inspecting and Certifying Secondary Containment Systems of Aboveground Petroleum Storage Tanks at Major Oil Storage Facilities

New York State Department of Environmental Conservation

DEC Program Policy

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I. Summary:

This program policy provides guidance on the design and construction of secondary containment systems at major oil storage facilities (MOSF) in New York State. In addition, this document provides guidance on the five year in-depth evaluation of these secondary containment systems. Elements of this guidance document may be used under a consent order at a petroleum bulk storage (PBS) facility.

II. Policy:

This program policy provides guidance on the design and construction of secondary containment systems and the evaluation of those systems. The guidance is intended to assist operators in complying with the associated MOSF license conditions and underlying statutory and regulatory requirements. In addition, the guidance will ensure that compliance reviews of secondary containment systems by Regional MOSF licensing staff are conducted uniformly in each of the New York State Department of Environmental Conservation's (DEC's) nine regions.

When completing an inspection of an MOSF secondary containment system, owners must understand the criteria that must be met, how to determine if their systems meet those criteria, and how to properly document the evaluation. The attached guidance addresses each of these issues. Overall, the performance criteria for a secondary containment system are defined in terms of the containment volume, permeability, compatibility, and structural integrity. The guidance explains various procedures for evaluating performance and establishes a uniform approach to documenting the results of the inspection.

III. Purpose and Background:

A. Purpose:

The purpose of this program policy is to provide guidance on the design and construction of secondary containment systems and on five year in-depth inspections of secondary containment systems.

The design and construction section provides guidance on site investigations, including references to consensus standards. That section also provides guidance on design and construction that is material-specific, including natural/native soil, clay, spray-on liners, synthetic liners, asphalt liners, concrete containment systems, and steel containment systems.

The 5-year certification, testing, and inspection section focuses on evaluating the structural integrity, volume, permeability, and compatibility of secondary containment systems. In addition, it provides guidance on material-specific inspections addressing structural integrity, compatibility and permeability. It also provides guidance on the number of samples to be taken, required testing, and the reporting format. In addition, it references industry standards and related test methods that may be used to demonstrate compliance with the secondary containment requirements.

As a general principle, the guidance requires a physical test of the secondary containment system whenever visual inspections cannot conclusively confirm the structural integrity of the system. At a minimum, for containment systems with ballast, for every 10,000 square feet of the containment area, 100 square feet of the ballast should be removed and the exposed area visually inspected.

B. Background

Under section 174 of Article 12 of the Navigation Law (NL), the DEC is responsible for licensing facilities with a total combined storage capacity of 400,000 gallons or more of petroleum. Regulations contained in 17 NYCRR Part 30 and 6 NYCRR Part 610 implement NL section 174. Among other things, Part 30 requires that an applicant for a license or renewal thereof obtain a certification from the DEC that it has implemented or is in the process of implementing New York State and federal plans and requirements for the control, containment, and removal of petroleum discharges. Part 610 sets forth requirements for obtaining such a certification, including compliance with 6 NYCRR Parts 613 and 614.

Section 613.3(c)(6) of the New York State Petroleum Bulk Storage (PBS) regulations requires tank owners to install secondary containment systems around any aboveground tank which:

- has a capacity of ten thousand (10,000) gallons or more; or
- is less than 10,000 gallons, and could “reasonably be expected to discharge petroleum to the waters of the State.” Separate guidance that explains this subject can be found at <http://www.dec.ny.gov/regulations/2387.html> (currently SPOTS #17).

In addition, section 613.3(c)(6) sets forth the following performance standard for secondary containment systems.

“(i) The secondary containment systems must be constructed so that spills of petroleum and chemical components of petroleum will not permeate, drain, infiltrate or otherwise escape to the ground-waters or surface waters before cleanup occurs. The secondary containment system may consist of a combination of dikes, liners, pads, ponds, impoundments, curbs, ditches, sumps, receiving tanks and other equipment capable of containing the product stored. Construction of diking and the storage capacity of the diked area must be in accordance with the National Fire Protection Association (NFPA) Standard No. 30, section 2-2.3.3 [see subdivision 6 NYCRR 613.1 (g)].

(ii) If soil is used for the secondary containment system, it must be of such character that any spill onto the soil will be readily recoverable and will result in a minimal amount of soil contamination . . .”

Furthermore, MOSF special license condition Section 3(j) requires that an in-depth secondary containment integrity inspection be performed at least once every five years. Such in-depth inspections

must be conducted under the supervision of, and certified by, a New York State licensed and registered Professional Engineer (NYSPE).

There are many variables that affect the integrity and performance of a secondary containment system. Therefore the DEC encourages high quality design, construction and maintenance to reduce the difficulty of completing the 5-year in-depth evaluation.

IV. Responsibility:

The DEC's Regional MOSF licensing staff are responsible for implementing this policy in consultation with Central Office technical and legal staff. The Bureau of Technical Support of the Division of Environmental Remediation (DER) is responsible for maintaining this program policy.

V. Procedure:

Follow the attached guidance document to inspect and certify secondary containment systems of aboveground petroleum storage tanks at MOSF.

VI. Related References:

1. Article 12 of the Navigation Law
2. 6 NYCRR Parts 610, 611, 612, 613, & 614 (DEC regulations)
3. 17 NYCRR Part 30 & 32 (DOT regulations)
4. 40 CFR Part 112 Spill Prevention, Control and Countermeasures Plans (federal regulations)
5. 40 CFR Part 280 Underground Storage Tanks (federal regulations)
6. 33 CFR Parts 151, 154, 155, 156 (US Coast Guard Operations Manual)
7. Technological Background and Quality Control/quality Assurance for New York State (NYS) Department of Environmental Conservation (DEC) Spill Response Program, March 1991
8. Analytical Handbook, the New York State Department of Health (NYSDOH)
9. Analytical Services Protocol, the NYS DEC.
10. NYS DEC Division of Environmental Remediation DER-11, "Procedures for Licensing Onshore Major Oil Storage Facilities", SPOTS 10 "Secondary Containment System Aboveground Storage Tanks" and Spots "Alternative to Secondary Containment for Small Petroleum ASTs"
11. ASTM D 420 "Standard Guide to Site Characterization for Engineering, Design, and Construction Purposes"
12. ASTM D 6429 "Standard Guide for Selecting Surface Geophysical Methods"
13. ASTM D 6432 "Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation"
14. ASTM D 5777 "Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation"
15. ASTM D 6820 "Standard Guide for Use of the Time Domain Electromagnetic Method for Subsurface Investigation"
16. ASTM D 5434 "Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock"
17. ASTM D 422 "Standard Test Method for Particle-size Analysis of Soils"

18. ASTM D 2216 “Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass”
19. ASTM D 2937 “Standard Test Method for Density of Soil in Place by the Drive-cylinder Method”
20. ASTM D 2937 “Standard Test Method for Density of Soil in Place by the Drive-cylinder Method”
21. ASTM D 4318 “Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils”
22. ASTM D 5747 “Standard Practice for Tests to Evaluate the Chemical Resistance of Geomembranes to Liquids”
23. ASTM D 1587 “Standard Practice for Thin-walled Tube Sampling of Soils for Geotechnical Purposes”
24. ASTM D 5093 “Standard Test Method for Field Measurement of Infiltration Rate Using a Double-ring Infiltrometer with a Sealed-inner Ring”
25. ASTM D 1990 “Standard Practice for Establishing Allowable Properties for Visually-graded Dimension Lumber from In-grade Tests of Full-size Specimens”
26. ASTM D 5126 “Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone”
27. ASTM C 597 “Standard Test Method for Pulse Velocity Through Concrete”
28. ASTM D 1140 “Standard Test Methods for Amount of Material in Soils Finer than the No. 200 (75-um) Sieve”
29. ASTM D 2434 “Standard Test Method for Permeability of Granular Soils (Constant Head)”
30. ASTM D 5322 “Standard Practice for Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids”
31. EPA Publication EPA 510-b-001 “Expedited Site Assessment Tools for Underground Storage Tank Sites, Chapter III, Surface Geophysical Methods”
32. US Army Corps of Engineer Em(Engineering Manual) 1110-1-1804 “Geotechnical Investigations, ENG 1836, ENG 1836a”
33. US Army Corps of Engineer Em(Engineering Manual) 1110-1-1802 “Geophysical Exploration for Engineering and Environmental Investigations”
34. US Army Corps of Engineer EM(Engineering Manual) 1110-2-2002 “Evaluation and Repair of Concrete Structures”
35. NFPA 30 “Flammable and Combustible Liquids Code”
36. 40 CFR 112 “Oil Pollution Prevention and Response; Non-transportation-related Onshore and Offshore Facilities; Final Rule”
37. American Welding Society (Aws) D1.1-96 “Structural Welding Code-steel”
38. API 351 “Overview of Soil Permeability Test Methods”
39. API 620 “Design and Construction of Large, Welded, Low-pressure Storage Tanks”
40. API 653 “Tank Inspection, Repair, Alteration, and Reconstruction”
41. API 650 “Welded Steel Tanks for Oil Storage”
42. API 651 “Cathodic Protection of Aboveground Petroleum Storage Tanks”
43. EPA Method 9090 “Compatibility Test for Waste and Membrane Liners”
44. ASTM D 3740 “Standard Practice for Minimum Requirements for Agencies Engaged in the Testing And/or Inspection of Soil and Rock as Used in Engineering Design and Construction.”

Attachment

DER Program Policy

DER-17

**Guidelines for Inspecting and Certifying Secondary Containment
Systems of Aboveground Petroleum Storage Tanks at
Major Oil Storage Facilities**

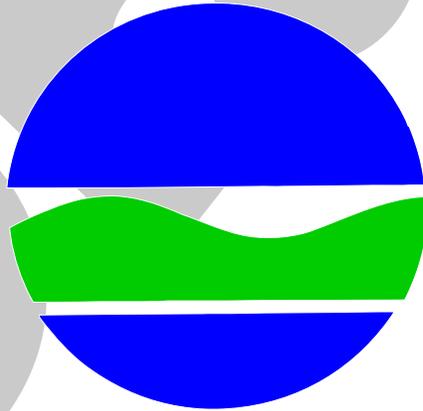


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Guidelines for Inspecting and Certifying Secondary Containment Systems of Aboveground Petroleum Storage Tanks at Major Oil Storage Facilities

1 Initial Design and Construction

1.1 Site Characterization

1.1.1 Investigation

To design and construct an effective and acceptable secondary containment system, it is vital that the facility owner have a thorough knowledge of the site. To get this information, a professional engineer or hydrogeologist experienced in site characterization should conduct a site hydrogeological characterization study (including borehole and surface soil samples) using properly established geophysical methods.

A thorough field description of the materials encountered during the site investigation is important for the design and construction of the secondary containment system. Guidance on field logging of subsurface explorations of soil and rock can be found in American Society for Testing Materials (ASTM) Standard Guides D 5434 and D 5753.

The following items are of interest in the site investigations:

- site stratigraphy (depth, limits and extent);
- soil types;
- depth to groundwater;
- seasonal effects on groundwater;
- aquifer identification; and
- engineering properties of soils including permeability, compaction, gradation, etc.

1.1.2 Soil and Rock

For the construction of secondary containment systems where natural/native soil is used as part of the system, a thorough description of the soil(s) color, soil type, particle size distribution, moisture content, consistency, structure, and density is needed. A permeability test is also required. The test procedure should be in accordance with nationally recognized and generally accepted professional standards.

1.1.3 Hydrogeological Conditions of the Site

A key component of site characterization is a thorough subsurface investigation of the proposed area of the secondary containment system. The information, tabulated and illustrated in drawing or mapping, should include soil types, density, strata and boundaries, groundwater levels during the year, flow direction, flow rate, and any underground objects (e.g., piping, sewer, tanks, vaults, etc).

For the construction of new facilities or tanks, including secondary containment, chemical analysis of the soil and/or groundwater may be needed to provide information regarding current conditions and for future reference at the site. Where chemical analysis is necessary, the analytical parameters used should be relevant and correspond to the product(s) to be stored, currently stored, or previously stored at the site. All data, Quality Assurance/Quality Control (QA/QC) information, laboratory reports, and test

methods should be maintained for the life of the tank system.

If, during an investigation, unreported contamination is encountered, such contamination must be reported immediately to the New York State Department of Environmental Conservation (DEC) through the spills hotline (1-800-457-7362 within New York State; 518-457-7362 from outside New York State).

1.2 Design of the Secondary Containment System

Purposes of the Secondary Containment System - Secondary containment systems are intended to prevent releases to the environment from tank rupture, equipment failure, vandalism, operation error, and overfills. The entire secondary containment system, including walls and floors, must be capable of containing petroleum product and must be constructed so that any discharge from the primary storage system (tanks and pipes located in the secondary containment system) will not escape the containment system before cleanup occurs. Accordingly, secondary containment systems should be designed by experienced licensed engineers that are familiar with both the operating requirements of the facility and the types of materials that are to be used in the secondary containment system. The design engineer is expected to be very familiar with the relevant regulatory requirements, codes, standards, and industry practices applicable to such systems, including fire codes, and with New York State and applicable federal requirements.

The following must be included in the design of a secondary containment system.

- The basis of design (rationale and principles) for the design of the secondary containment system, from the foundation subgrade to the top surface of the system. The basis of design needs to account for the subsurface conditions (soil stratigraphy and hydrogeology) existing at the site.
- The compatibility of the proposed liner material with the products stored at the facility.
- The impact of the liner on existing tanks and ongoing operation of the facility. The impact of the liner system on the primary containment tanks and appurtenances must be addressed.
- Applicable industry standards (e.g., NFPA 30) and practices for the secondary containment system.
- The stability, durability, and bearing capacity of the secondary containment system. Traffic from pedestrian or vehicular access onto or through the containment system, necessary safety measures, and the layout of the structural elements, seams, joints, etc. should be clearly specified and indicated in the design.
- The ability of the liner to accommodate drainage of storm water from the tank field without release of any petroleum. The accumulation of precipitation, including rain and snow which collects within the secondary containment system must be controlled by a manually operated pump or siphon, or a gravity drain pipe which has one manually controlled dike valve accessible from outside the dike. The DEC recommends against the use of a gravity drain pipe. The liner system drainage must address the Division of Water (DOW) requirements stipulated under the State Pollutant Discharge Elimination System (SPDES) program. The system also must take into account the drainage of fire water and placement of fire traps to safely remove fire water from within the secondary containment system during a fire emergency.

- The DEC’s minimum acceptable standard for volume. The DEC considers the minimum acceptable volume for a secondary containment system to be:
 - (1) 110% of the largest tank in the containment area; or
 - (2) the entire capacity of the largest single tank plus sufficient room for freeboard to contain precipitation, whichever is greater. “Sufficient freeboard” is freeboard sufficient to contain precipitation from a 25-year storm event. Additional capacity is needed for systems with interconnected tanks (see section 2.1.5).
- A liner system that allows standard underground piping and/or tank bottom cathodic protection (CP) systems to remain operationally effective. The liner system shall not impede the periodic testing or maintenance of the CP system. Refer to the applicable American Petroleum Institute (API) RP 651 and National Association of Corrosion Engineers (NACE) requirements.
- A drain system; groundwater or under drain system that is not connected to the storm water drain system within the secondary containment areas. Designs of drain systems within the secondary containment area must take fire hazards into consideration.
- Location of groundwater monitoring wells outside of the secondary containment system, except under certain conditions. For example, a facility may be located between two other facilities or it may require remediation from a prior release. Under such circumstances, the operator may have no choice but to install monitoring wells within the diked area to monitor for a leak or release. When this situation occurs, the design must account for the presence of these wells and appropriate practices must be incorporated to prevent a release from within the secondary containment system from entering the wells. The use of liquid tight caps or monitoring wells that exceed the height of the dike wall are necessary when ground water monitoring wells are located within the secondary containment area [refer to DER-11 Appendix A.(2.1) “Installation of Monitoring Wells”].

1.2.1 Liner Selection Criteria

The main criteria for the selection of a liner are the physical properties (tensile, yield, shear strength, and general tear resistance), impermeability, and chemical resistance of the liner material. There are fundamental differences among liner systems. These differences make installation-related factors key to liner selection. Installation is as important to liner integrity as the physical properties, impermeability, and chemical resistance of the base liner material. Considerations must include liner cover, tank field drainage, cathodic protection, seaming techniques and methods used to join liner panels to existing structures such as tank ring-walls, pipes, or other tank field equipment. The results of the site investigation also will play a role in the selection of liner material. Installation of liner systems can be very challenging because of the large number of sealing and liner connection points. The integrity of the liner system is dependent on attaining a liquid-tight seal at all attachment points. Successful installation depends on quality assurance and careful attention to detail during the construction process.

The long term integrity of a liner is dependent on the subbase preparation, the physical strength of the liner itself, its resistance to chemical degradation in the event of a release, and its resistance to the effects of aging and environmental degradation.

1.3 Construction of Secondary Containment Systems

The ability of a secondary containment system to perform in accordance with the intent of the designer will depend upon the basis of the design and the quality of its construction. The following issues should be considered during construction.

- Foundation soil underlying the proposed facility should possess geophysical parameters that are sufficient to support construction, operation and maintenance.
- Results of site investigations.
- Permeability rate to water that meets the specification of Table 6 of section 2.1.3.1 below.
- The construction of a test area is recommended to establish the allowable range of soil particle size distribution and Atterberg limits, water content, dry density, lift thickness, number of lifts, compaction effort, and equipment.
- A construction quality assurance program with a written plan should be in place. The plan should identify steps that will be used to monitor and document the quality of materials and the condition and manner of their installation. It should also spell out the roles and responsibilities of the contractor, owner, and quality assurance (QA) provider.
- During construction, the clean soil materials being used should be sampled in appropriate numbers at reasonable sequences, and their types, structural dimensions and compaction density confirmed to be within the design specifications.
- During the construction of a soil-clay liner, tests of the in-place liner should be completed to verify that the design requirements for thickness, density, and permeability are met.
- When a synthetic liner is used, the integrity of the liner and its seams should be inspected and tested in accordance with the manufacturer's requirements and any relevant national standard. The integrity of liner seams needs to be verified by a vacuum box testing or other acceptable technique before being covered.
- A log of daily construction quality control/quality assurance (QA/QC), inspection, verification, findings, events, and procedures during construction should be kept.

Below are guidelines for the design and construction of secondary containment systems based on materials used.

1.3.1 Clay (Compacted) Liner

Clay is generally chemically compatible with most liquids, but it must be protected from frost damage and maintained to ensure adequate moisture content. Only properly installed and well maintained clay systems will meet the DEC's secondary containment requirements. The proper maintenance of clay liners is very important since clay liners are prone to desiccation and cracking in dry environments. In most cases, the thickness of a clay liner should be at least two feet, compacted in 6-8 inch lifts and to 95% of the maximum dry density. Clay liners must be protected from freeze-thaw damage. Although clay is chemically compatible with most liquids, it can be degraded when in contact with high concentrations of salts, especially calcium or magnesium. These concerns should be taken into consideration when choosing a ballast (cover for the clay or compacted soil). Material sources for compacted clay should be monitored for consistency with design specifications. Table 1 below provides relevant design and construction methods for clay.

Table 1: Standards for Clay and Compacted Soil Construction and Installation

Work	Applicable Standards	Title
Design and Construction	EPA/530/SW-86/007 March 1986	Design, Construction, and Evaluation of Clay Liners for Waste Management Facilities
Installation of Geosynthetic Clay Liner (GCL)	ASTM 6102	Standard Guide for Installation of GCL
Determining Properties	ASTM D 4318	Liquid Limit, Plastic Limit, and Plasticity Index of Soil

1.3.2 Natural/Native Soil

The hydraulic conductivity of natural soils is generally anisotropic: that is, the vertical permeability can be different from the horizontal permeability. In addition, due to the heterogenous nature of the natural soil deposits, the permeability can vary substantially within a geological unit. Therefore, only homogenous or consistent deposits with less variable hydraulic conductivity is recommended for use in the construction of a secondary containment system. The upper two feet of the natural clay or soil must be reworked to ensure that there is a homogenous and consistent layer within the secondary containment area. The coarse grain must contain a significant quantity of silt or clay in order to achieve the required impermeability. Penetrations through natural soil liquid barriers are difficult to seal effectively, therefore appropriate precautions should be taken during construction. Trench backfill should be less permeable than the surrounding soil; the use of bentonite to enhance these differences is encouraged. Quality assurance is necessary to ensure the consistency of the natural soil used in the secondary containment system. The quality assurance should include geophysical and geological mappings, test pits, drilling, and a hydraulic conductivity test. Sufficient numbers of samples should be taken at carefully selected test pits or drilling locations. In most cases, one sample per 1000 square feet will be sufficient. Standards from Table 1 above can also be used for natural soils.

1.3.3 Synthetic Liners

Synthetic liners for secondary containment purposes are generally divided into four main groups:

- supported coated fabrics or laminates, such as polymer films applied to a high-strength textile backing;
- unsupported, extruded plastic sheet geomembranes, such as high density polyethylene (HDPE);
- geosynthetic/clay liner (GCLs), which include natural material such as bentonite affixed to a synthetic geotextile or plastic membrane backing; and
- spray-on coatings that are applied to a geotextile backing.

A synthetic liner may be installed as either an exposed or buried liner. Subgrades should be uniformly graded and free from abrupt grade changes and breaks in order to facilitate installation. Installation of a geomembrane or liner should only be performed by qualified and experienced technicians. Exposed liners should be installed on materials that are stable and free of groundwater pressures. Exposed liners

must be able to withstand sunlight damage for the entire usage period of the liner. For buried liners, maximum particle size and angularity of the protective cover should be specified. Vehicular traffic zones should be marked if the protective cover of a buried liner over the entire surface of the system is not adequate to protect the liner from bearing load. Bentonite incompatibility with calcium and magnesium should be taken into consideration when dealing with geosynthetic clay layers.

Generally, geomembranes are impermeable to liquids, but they are permeable to vapor to a degree that depends on the solubility of the liquid in the polymer, temperature, and the thickness of the membrane. The most important physical and mechanical attributes of the liner that determine its suitability for a given application are thickness, density, mass per unit area, tensile properties, tear resistance, hydrostatic resistance, and puncture resistance. Other key physical properties include linear expansion properties, cold temperature properties, resistance to ultraviolet light, resistance to soil burial, and dimensional stability.

The facility operator shall provide the DEC with all appropriate physical, mechanical, and chemical test information that supports the capabilities of the materials to meet the DEC minimum requirements for liners. Information or data from the manufacturer of the geosynthetic liner or sealer may be acceptable. The manufacturer’s installation guidelines should be followed. Refer to Table 2 for the relevant standards.

Table 2: Standards for Geosynthetic Liner Construction and Installation

Work	Applicable Standard	Title
Evaluates the Stress/time Properties of Geosynthetics	ASTM D 5514	Standard Test Method for Large Scale Hydrostatic Puncture Testing of Geosynthetics
Installation QA Guidelines	ASTM D5889	Standard for Quality Control of Geosynthetic Clay Liners
Installation of GCL	ASTM 6102	Standard Guide for Installation of GCL
Designing and Installing Liners	EPA’s Guide for Industrial Waste Management; Chapter 7: Section B	Designing and Installing Liners, Technical Consideration for New Surface Impoundment, Landfills, and Waste Piles http://www.epa.gov/industrialwaste/chapters/chapter7b.pdf
Construction Quality Assurance Guidelines	EPA/600/r-93/182	Quality Assurance and Quality Control for Waste Containment Facilities

1.3.4 Asphalt Liner

An asphalt liner by itself is not an acceptable secondary containment system because it is not chemically compatible with petroleum. However, secondary containment systems that are constructed with asphalt and a compatible sealant or liner are acceptable. Asphalt is an example of a bituminous liner. Bituminous liners require a compacted, smooth subgrade. Spray-on application methods require the subgrade to be primed. Subgrade cracks must be patched and primed. Some applications require geotextile fabrics with primer coats. Table 3 below provides standards for asphalt construction and installation.

Table 3: Construction and Installation Guidance for Asphalt

Work	Recommendation	Title
Asphalt Concrete Design	Asphalt Institute's Manual Series # 2 (MS-2)	Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types
Types of Asphalt and Uses	Asphalt Institute's Manual Series #12	Asphalt in Hydraulics (MS-12)
Hot Mix Asphalt Materials, Mixture Design, and Construction	National Asphalt Pavement Association Education Foundation	Hot Mix Asphalt Materials, Mixture Design, and Construction by F. L. Roberts, etc.

1.3.5 Concrete Containment System

Extensive site preparation is necessary for concrete containment structures. The subgrade for slabs should be well drained, free of organic materials, frost and other deleterious materials, and of uniform bearing capacity. The framework must be designed and installed consistent with the objective of creating a barrier to liquids. Concrete containment systems must have adequate and compatible waterstops in all the joints. Extreme weather conditions, frost heaves, and differential movement should be taken into consideration when designing or constructing a concrete secondary containment system. Depending on the type of petroleum stored, concrete containment may need a sealant or geosynthetic membrane. Where a sealant is used, it should be tested for compatibility as stated in section 2.1.4.1 (Sealant and Tapes) of this document. Control joints must be sealed and maintained.

Table 4 (see page 8) provides design and construction guidance for a concrete containment system.

Table 4: Recommended Standards for Concrete Containment Construction and Installation

Work	Recommendation reference or Methods	Title
Design and Installation	American Society of Civil Engineers (ASCE)	Concrete Watertight Structures and Hazardous Liquid Containment
	American Concrete Institute, ACI 350R-01	Environmental Engineering Concrete Structure
	American Concrete Institute, ACI 350.03-01	Liquid-Containing Concrete Structures
	ASTM C 1157-03	Standard Performance Specification for Hydraulic Cement
Surface Preparation & Coating	International Concrete Repair Institute (ICRI) Technical Guideline 03732	Guide for Selecting and Specifying Surface Preparation for Sealers, Coatings and Membranes

1.3.6 Steel Containment System

Steel is generally impervious to liquids for secondary containment system purposes. However, leakage can occur through severe corrosion, defects, welded or bolted seams, or connections with other materials. Steel is chemically resistant to petroleum. However, water and other oxidants can contribute to corrosion. At a minimum, all welded seams should meet the visual acceptable standards listed in American Welding Society (AWS) D1.1-96 “structural welding code-steel.” Welding technicians should be certified through an approved or a nationally recognized agency. Corrosion protection is recommended for all steel or steel construction in the secondary containment system, especially when it is in direct contact with the soil. Steel systems that are subject to corrosion should be painted.

Table 5 (see page 9) provides construction standards for steel containment systems.

Table 5: Construction Standards for Steel Containment Systems

Work	Applicable Standard	Title
Corrosion Protection	National Association of Corrosion Engineers (NACE) 6G197 or Society for Protective Coatings (SSPC) TU-2	Design, Installation and Maintenance of Coating Systems for Concrete Used in Secondary containment system
Manufacture, Inspection & Testing	Steel Tank Institute (STI) Standard F911-91	Manufacture, Inspection and Testing of Open-Top Diked Secondary containment system Tanks
Design and Construction	American Petroleum Institute (API) Standard 620	Design and Construction of Large, Welded, Low-Pressure Storage Tanks
Design, Construction, Operation, Maintenance, Inspection	API Standard 2610	Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities
Secondary Containment System	National Fire Protection Association (NFPA) 30	Flammable and Combustible Liquid Code

1.4 Installation

Proper installation is critical with any liner system. The fundamental differences between liner systems make the liner selection process sensitive to installation-related factors. Installation considerations are as important as the physical properties, impermeability and chemical resistance of the base liner material. Seaming and attachment methods used to join liner panels to existing structures such as tank ring-walls, pipes, or any other structure within the tank field are important and differ depending on the liner type.

Generally, liners last for ten (10) to twenty (20) years. The exact lifetime is dependent upon the type, installation and maintenance. Therefore, provisions must be made for future maintenance, including creating access over the liner and minimizing liner penetrations during installation. The secondary containment system at an MOSF provides a challenging installation problem because of its size and the many appurtenances that usually exist. When installation is at an existing facility, utilities such as drainage, cathodic protection (CP) systems, conduits, stairways, and roads often must be relocated before a dike liner installation. In addition, significant drainage and grading work is often necessary to prepare the area for replacement of the liner. Adequate consideration must be given to the relocation of utilities so as to prevent liner penetration during installation. If any liner penetration is absolutely necessary, a positive seal between the liner and penetration must be constructed to prevent leakage along the penetration.

1.4.1 Geomembrane Seams

Seaming is the most important element of a geomembrane installation. Seaming can either be done at the factory or in the field. Factory seams in most cases result in a more consistent joint of good quality. Generally, manufacturers of synthetics, especially coated fabrics, fabricate custom factory seams so as to ease the installation process and reduce the necessity for field seams. Almost every synthetic liner installation will require some field seaming. The DEC recommends an overlapping double seam when seaming in the field. Different manufacturers may require different and varying details on seaming particular products. For every liner material selected, an experienced installer with knowledge of the product is essential to the success of the project.

1.4.2 Attachments to Tanks, Ring-walls, and Appurtenances

The integrity of the liner installation is highly dependent on attaining a liquid tight seal at all attachment points. Each manufacturer has developed equipment and methods for making the connection to tanks, ring-walls, pipes and other appurtenances (such as pumps, walkways or any other obstruction that may exist in the floor of the diked area). Therefore, the use of appropriate manufacturer's recommended equipments and method is strongly encouraged. Connections between liner systems and tank bottoms must be such that releases from tank bottoms cannot go directly underneath the liner.

Experience in the waste containment industry suggests that leakage may be expected in almost any liner installation. This leakage is usually attributed to factors other than permeation through liner panels, such as seepage at seams or points of attachment. Seams are the weakest points of a liner. Many problems encountered in secondary containment system originate at seam locations.

Although certain sections of a liner system may be hydro tested, it is usually not possible to hydrotest the entire liner system, as would be the usual practice for landfill or pond liner construction. (Hydrotesting the entire system would require filling the entire containment area with water, which could cause problems for tanks and equipment installed within the diked area.) Therefore, it may not be possible to verify the leak tightness of the entire liner system once installed. These points underscore the importance of careful attention to detail and quality assurance during construction.

1.5 Site Map

A site map showing the location of all surface water, buildings, observation, monitoring and recovery wells, all tanks, pipelines, sewers and their respective secondary containment system areas, product transfer areas, and spill cleanup equipment storage is required. Flow direction of surface and groundwater should be indicated. The scale used for the site map should be such that all of the referenced map features (tanks, transfer areas, wells, etc.) are readily visible. The site map from the Spill Prevention, Control and Countermeasure (SPCC) document may meet, or can be modified to meet, this requirement.

1.6 Final Inspection and Testing of the Secondary Containment System

Proper design and good QA/QC during construction are important elements for an acceptable containment system. The inspection and testing of a newly constructed liner system should include:

- visual inspection for any anomalies with any functional item of the containment system;

- structural integrity analysis;
- verification of containment capacity using as-built survey data; and
- compliance with all manufacturer's specifications for installation and testing.

At the end of construction, the secondary containment system should be inspected to verify that it has been built as designed; its structural dimensions, size or volume, and slope of the containment bank should be measured. Equipment installations such as sump pump, rainwater discharge valve, etc., and their function should be confirmed. A checklist should be established, followed and noted for any areas of concerns.

The field testing of geomembranes requires different and additional consideration than those required for the field testing of clay liners or GCLs. The performance of geomembranes depends on its physical properties and the quality of its field constructed seams, therefore the field testing programs for geomembranes must address seaming and construction quality assurance.

The secondary containment system must have a permeability rate as low as 10^{-7} cm/sec depending on the product stored (see Table 6). API 351 "Overview of Soil Permeability Test Methods," is the starting point for selecting an appropriate permeability testing method. A liner manufacturer's certification that the liner meets required permeability may be acceptable.

Photographic records of the containment system and its key elements/areas are recommended.

1.7 Submittal Requirement and Record Keeping

A design report must be submitted to the DEC at least 90 days before the anticipated date of construction. The design report must contain a detailed schedule ending with the date for accepting the first delivery to tanks in the secondary containment area. In some cases, the DEC may approve the continued service of tanks in the construction area. The design report must be approved by the DEC before the commencement of construction. This approval may be based on the conceptual design of the system, and does not relieve the owner from the responsibility of ensuring that the details of the design meets both acceptable engineering practice and required state and federal regulations.

An as-built plan must be submitted to the DEC and it must include the following information:

- construction plan;
- final inspection report;
- site map;
- volume calculation of the secondary containment system;
- compatibility test or manufacturers compatibility certification;
- permeability calculation/ manufacturers certification; and
- NYSPE certification.

Where available, test results for appropriate characteristics such as strength and weathering and chemical compatibility should be kept for the life of the secondary containment system or liner and be included in the report package for review.

2 Five-Year Certification, Testing and Inspection

2.1 Performance Criteria

The certification of a secondary containment system requires a thorough evaluation of its structural integrity, permeability, compatibility, and volume. These factors are defined as follows:

- *Structural Integrity*: The quality or soundness of a given material used in the construction of the secondary containment system; the ability of the secondary containment material to continue providing adequate support and strength; the absence of physical flaws such as separation of seams, holes, cracks, subsidence, penetrations, etc.
- *Permeability*: The rate of flow of a liquid or product through a porous material; a measure of a material's ability to hold liquid or product such that it does not permeate, drain, infiltrate or otherwise escape.
- *Compatibility*: The ability of two or more materials to maintain their respective physical and chemical properties upon contact with one another under conditions likely to be encountered in the design life of the secondary containment system.
- *Volume*: The total capacity measured in US gallons; tank volume or "storage capacity of a container means the shell capacity of the container." (40 CFR 112.2)

There are many variables that affect the integrity and performance of a secondary containment system. Most of these variables can be eliminated or reduced by the use of high quality construction and good maintenance practices. Therefore, DEC encourages high quality design, construction, and maintenance to reduce the difficulty of completing the 5-year in-depth evaluation.

Physical testing of the components of the containment system is not necessarily required for each inspection. The evaluation of a secondary containment system must include a visual inspection and document review. The visual inspection and document review will include elements of the system's structural integrity, permeability, chemical compatibility, and verification of sufficient volumetric capacity. The need for physical testing will depend on the results of the visual inspection and document review. Physical testing must be conducted where the structural integrity, permeability, or chemical compatibility of a secondary containment system cannot be adequately determined.

The material with which the secondary containment system is constructed will determine the specifics of the field inspection program. The basic elements of the inspection are detailed below. However, not all items listed will be applicable or appropriate for all liner systems.

2.1.1 Visual Inspection

All secondary containment liners must have a visual inspection. All visual inspections must be documented and should include photographs of suspected areas of degradation. The location and magnitude of the following items should be noted and recorded:

- inability of the liner system to impound water at locations where water would obviously be anticipated to be retained during normal storm events;

- cracks, bulges, stains, chips, seepages in the liner system;
- damage from animals or vegetation which compromise the liner integrity;
- discoloration, erosion, or chemical degradation of the liner;
- improper or deferred maintenance of the liner system;
- dike wall, foundation, or embankment movement, settlement or deterioration which does or may compromise the integrity of the liner system;
- degradation of the liner system from storm water flow or erosion of the secondary containment system;
- intrusion of groundwater into or above the secondary containment system;
- degradation of the liner system at penetrations (piping, supports, wells, foundations, pads, etc.);
- damage to the liner system from equipment, vehicles, foot traffic, frost heave, etc.; and
- observations of work in progress or new additions to the secondary containment system subsequent to the original construction or last documented inspection.

2.1.2 Structural Integrity Evaluation

Stormwater retention after a storm event is the most crude way of assessing the integrity of secondary containment system. The inability of the secondary containment system to collect water after a storm event indicates a gross failure of the system, however the presence of stormwater is not evidence of the proper performance of the system.

The material(s) used in the construction of a secondary containment system must be inspected to ensure that it continues to function as expected five or more years after installation. If contact with stored products is anticipated to materially affect the structural integrity of the liner system, then areas exposed to the petroleum products will require additional review to ensure that the liner system has not been degraded at the point of contact. The inspection of a secondary containment system should begin with a review of the design and construction records, if available. In any case, the inspection must consist of an in-depth evaluation of the system's overall integrity. The items to be inspected and tested may vary, depending on the construction material used.

The life expectancy of a liner system is dependent on its resistance to the affects of environmental degradation, aging, and its resistance to damage caused by misuse or accident. The integrity evaluation of a secondary containment system should include:

- visual inspections as stated in section 2.1.1 above;
- an evaluation of the integrity of penetration and connections with compacted soil liners or other materials; and
- inspections and field testing specifically addressing failure modes.

The owner is responsible for determining the specific methods and procedures needed for evaluating the integrity of the containment system taking into consideration the type of liner, construction material, age and usage history of the system. Section 2.2 below, identifies and provides information on the typical failure modes of different liner systems. That information should be used in selecting and determining the specific methods and procedures needed to evaluate the structural integrity of the system.

2.1.3 Permeability Criteria

2.1.3.1 Permeability Limits

Petroleum products have different viscosities, therefore different containment systems will have different permeability rates depending on the product stored. As such, the DEC has developed product specific permeability rates (depending on the viscosity and storage temperature of the product) that will provide adequate protection to the environment. These product-specific permeability limits are listed in the Table 6 below. Where different products are stored in the same secondary containment area, the secondary containment area will be held to the standard of the lightest product (i.e., product with the lowest viscosity) stored. If a petroleum product that is not listed below is stored in a given containment area, the containment will be held to the standard of the closest most stringent listed petroleum product. A secondary containment system's liner material that meets this minimum limit will be deemed acceptable by the DEC.

For recommendations on sampling requirements, please see "Material Specific Inspections" in section 2.2 of this document.

Table 6: Acceptable Permeability Limit for Specific Product Stored

Product	Permeability Limit (cm/sec) (Permeability in Reference to Water)
Gasoline	1×10^{-7}
#2 Fuel Oil	1×10^{-6}
#4 Fuel Oil	3×10^{-6}
#6 Fuel Oil	1×10^{-5}
Asphalt	1×10^{-4}
Asphalt Emulsion (heated)	1×10^{-4}
Asphalt Emulsion (not heated)	1×10^{-6}

Permeability testing is always required at every 5-year inspection for the following liner systems:

1. clay liners;
2. geosynthetic/clay liners;
3. natural soil; and
4. asphalt.

There are various laboratory and field test methods that can be used to evaluate the permeability of these systems. However, the DEC prefers and recommends obtaining representative field samples and measuring liner permeability in the laboratory using the flexible wall permeameter test. Some of the most common methods are listed below.

Laboratory test methods (see section 2.1.3.3 and Table 7):

1. Constant head test
2. Falling head test
3. Flexible wall permeameter test (triaxial test)

Field methods (see section 2.1.3.4):

1. Borehole test
2. Gulf oil field test method
3. Flood test
4. Infiltrometer tests
5. Double tube test method
6. Air-entry permeameter

2.1.3.2 Exemptions

Permeability testing may be waived for the first “five-year in-depth evaluation” if the secondary containment system is constructed of:

1. a synthetic liner or spray-on liner with a written manufacturer’s guarantee. This guarantee must expressly cover and state the ability of the liner to maintain permeability equal to or higher than those limits in Table 6 above. In addition, it must also expressly cover the ability of the liner to maintain its chemical compatibility when in contact with stored product or exposed to environmental elements for a period of five years or more; or
2. concrete and meets the structural integrity criteria of section 2.2.5.1 of this document; or
3. steel and meets the structural integrity criteria of section 2.2.6.1 of this document.

2.1.3.3 Laboratory Test Methods

Although laboratory testing is performed under closely controlled conditions, the results are not necessarily representative of the actual permeability of the containment area. Laboratory methods are greatly dependent on the quality of samples obtained from the field, the handling of the sample, and the number of samples collected. In addition, laboratory methods often represent only a small sample of the actual field conditions. By removing soil samples for examination in the laboratory, these natural conditions can be altered. This is especially true for sands, silty soils and certain clays. Furthermore, some laboratory tests may rely on the use of remolded soil samples, which may not be representative of the actual field conditions. This section outlines the methods available for determining permeability in the laboratory. Table 7 summarizes the test procedures and outlines the advantages and disadvantages of the presented methods. The laboratory methods described here apply only to saturated soils.

Table 7: An Overview of Laboratory Permeability Test Methods

Permeability Test	Reference	Applicability	Advantage	Disadvantage	Procedure
Constant Head Test	ASTM D-2434 Cedergren, 1989	Laboratory test for coarse grained soils	<ul style="list-style-type: none"> -Simple test and inexpensive to perform. -Accurate for soils with permeabilities greater than 1×10^{-3} cm/sec. -Typically use a field bulk sample, no special drilling or sampling method. Provides accurate estimate of permeability for coarse grained soils. -Proven track record of use. -Provides good correlation data for well sorted soils. -Equipment readily available and can be performed by persons with basic knowledge of the method. 	<ul style="list-style-type: none"> -Remolded sample or nonuniform soils may cause a large variation in results. -Flow must be in one direction. -Results are dependent on small soil sample size, which may not be representative of the field conditions. 	<ul style="list-style-type: none"> -The soil sample is placed into the appropriate setup and a continuous supply of water is passed through it. -The water that passes through the sample, in a specified time, is collected. -The permeability is calculated.
Falling Head Test	ASTM D - 5084 Lambe, 1969. Stephens, 1988	Laboratory test for coarse grained soils and some fine grained soil	<ul style="list-style-type: none"> -Simple test and inexpensive to perform. For lower permeability soils (1×10^{-3} - to 1×10^{-5} cm/sec). -Typically use a field bulk sample only, no special drilling or sampling method. -Provides accurate estimate of permeability for coarse grained soils and some fine grained soils. -Proven track record of use. -Equipment readily available and can be performed by persons with basic knowledge of the method 	<ul style="list-style-type: none"> -If permeability of soil is low, evaporation of water may introduce an error in the measured results. -There can be large variation in results. Flow must be in one direction. -Dependent on soil sample size and quality of sample, which may not be representative of field conditions. 	<ul style="list-style-type: none"> -The soil sample is placed into the appropriate setup, with a standpipe connected to the top. -The standpipe is filled with water and the time required for the water level to drop to a lower point is recorded. -The permeability is calculated

Permeability Test	Reference	Applicability	Advantage	Disadvantage	Procedure
Flexible Wall Permeameter (Triaxial test)	ASTM D-5084	Laboratory Test for Fine-grained Soils	<ul style="list-style-type: none"> - Is representative of undisturbed conditions. - Prevents leaks and side flow between wall and soil. - Prevents movement of fines, which can lead to clogging or flushing which will provide inaccurate results. - Can measure permeability rates less than 1×10^{-7} cm./s. <p>Most appropriate for silty clay soils.</p>	<ul style="list-style-type: none"> -Dependent on quality of sample, which may not be representative of field conditions. -Test requires obtaining undisturbed tube samples for clay soils. These samples may be difficult or expensive to obtain. -Use of remolded or disturbed samples may provide less accurate results. -Requires specialized laboratory equipment and training. 	<ul style="list-style-type: none"> -The undisturbed sample is placed in the flexible wall chamber. -The seepage rate through the soil is calculated through drainage holes on the two ends of the chamber.

Reproduced courtesy of American Petroleum Institute (Table 2-1 “Laboratory Methods for Testing Permeability” pg 2-7 API 351, 1999)

2.1.3.4 Field Test Methods

Unlike the laboratory methods, field test methods are more representative of actual field conditions. Field methods avoid the difficulties involved in obtaining and setting up undisturbed samples in a permeameter and also provide information about bulk permeability, rather than merely the permeability of a small and possibly unrepresentative sample. However, field methods have several disadvantages, among them are the effect of localized conditions on the result and the limitations of the test methodology. Some localized conditions that adversely affect the result of a field method include the presence of fine grain soil and organics, void spaces, or the presence of large size particle at the test site. Following is an outline of different field test methods.

1. Borehole Test

Many variations of the borehole test exist, and they are generally applicable to all soil conditions. In general, borehole tests consist of pumping water into or out of drill holes in order to estimate the permeability of the soil. The “pumping in” form of test in many cases is more reliable than the “pumping out” form of the test. Only the "pumping-in" form of the test should be used when the soil sample is above the water table, and either the "pumping-in" or "pumping-out" test methods can be used in other conditions. The flow rate of the water into the borehole to maintain the level is measured at various times. Permeability is calculated using the flow rate at steady state conditions, considering the dimensions and geometry of the borehole and the elevation of the water table. The advantages of this test include the ability to measure the permeability of soils in the unsaturated zone, eliminating the need for observation wells, accounting for flow in all three dimensions, and the low cost. This method is not appropriate for estimating the permeability of thin layers of soil. For further information on the calculation of permeability from a borehole test, refer to the ASTM Standard D-5126, “Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone.”

2. Gulf Oil Field Test Method

The Gulf Oil Field Test is a simple method for determining permeability, similar to the borehole and slug test methods. The procedure includes placing a six-inch pipe in the soil and filling it with water to about two feet above the bottom edge. A falling head test is then performed inside the pipe to determine the soil permeability. Measurements of the water drop in the pipe are taken at 30-minute time intervals. The number obtained is plotted on a graph showing water level drop versus permeability, for either unsaturated or saturated soil. For this method, unsaturated soil refers to a groundwater level more than twelve inches below the bottom of the pipe, and saturated soil refers to groundwater less than twelve inches below (PACE, 1979). Before performing the test, it is necessary to determine the subsoil and groundwater conditions by using excavation test pits for every 3,000 square feet of area, but not less than two test pits. In addition, this test should be performed at the driest time of the year (PACE, 1979). Although this method has gained wide acceptance in the industry, it generally has variability in reported results and the repeatability of such results, and may not accurately predict permeability for soils with permeabilities lower than 10^{-5} cm/sec (ASTM, 1990; API 351, 1999).

3. Flood Test

A flood test involves the release of a measured volume of water into the secondary containment area to cover the base area of the secondary containment system. The height of the water level is then marked and recorded. In most cases, a 55 gallon drum filled with water is used as the control, and the water

level in the drum is also marked and recorded. Both systems are left exposed to the same environment for seventy-two hours. At the end of the exposure time (72 hrs), the water levels are recorded again. The percentage loss of water from both systems is calculated. The permeability of the secondary containment system (cm/sec) is calculated as follows:

$P = (A \times V) / (T \times S)$ where

A = % water lost from the secondary containment - % water lost from the control (55 gallon drum) (dimensionless)

V = Volume of water in the secondary containment system (measured in cm^3)

T = Time taken (72 hrs) (measured in seconds)

S = Surface area of the water in the secondary containment area (measured in cm^2)

When using this method, it is important to ensure that water does not adversely affect the tanks or any of the tank equipment within the secondary containment area. Flood tests should be limited to containment systems where the volume can be easily calculated.

4. Infiltrometer Tests

There are three types of infiltrometer that are used for permeability tests in the field; they include single-ring, open double-ring, and sealed double-ring infiltrometers. The single ring involves driving a ring into the soil and supplying water in the ring either at constant head or falling head condition. A double ring infiltrometer requires two rings: an inner and outer ring. The purpose is to create a one-dimensional flow of water out of the inner ring to simplify the analysis of data. Infiltrometers are useful because they can test large amounts of soil, and seepage can be made one-dimensional. Infiltrometers should not be used in highly fractured ground, very coarse soil, or heavy clays (except for the sealed double-ring infiltrometer). The disadvantage of these tests include difficulty in measuring low flow rates, long testing times, and inadequate saturation of the soil (API 351, 1999) Results maybe be compromised due to large evaporative losses and inadequate sealing of the ring.

5. Double Tube Test Method

The double tube test method measures both horizontal and vertical permeability and it can be used to test soil in the vadose zone. To perform this test, an auger hole is excavated to the desired depth for soil measurement. The hole is cleaned, and a 1 to 2 cm layer of coarse sand is added for protection. A tube is driven into the hole approximately 5 cm. and filled with water. A smaller tube is then driven inside the outer tube. A system of valves and stand-pipes is installed and water is added to both cylinders (API 351, 1999).

6. Air-Entry Permeameter

The air-entry permeameter is similar to the single-ring infiltrometer, except that the device is placed deeper into the soil and measures the air-entry pressure, which is used to estimate the permeability in the vadose zone. A sealed ring approximately 30 cm in diameter is driven into the soil approximately 15 cm. A water reservoir is attached to a standpipe on top of the permeameter. Water is allowed to infiltrate the soil through the standpipe, and the flow rate is measured from the decline in the water level of the reservoir. When the flow rate has stabilized, and a certain amount of water has infiltrated, the minimum pressure is achieved. The water supply is shut off and the depth to the wetting front is determined

(ASTM, 1990). An assumption inherent in this model is that the wetting front pressure head is closely approximated by air-entry pressure (API 351, 1999).

2.1.3.5 Calculating Permeability

Darcy's law defines permeability by the equation: $K = Q/(iA)$ where

K = permeability of the soil (cm/s)

Q = seepage rate (cm³/sec)

i = hydraulic gradient (dimensionless)

A = area perpendicular to Q (cm²)

By measuring the quantities of A, i, and Q from the laboratory or in-place test, the permeability rate can be calculated. The two common laboratory tests used to determine the variables needed to calculate the soil's permeability, which apply to Darcy's Law, are the "constant head" and "falling head" types. Common field tests used to determine the variables A, i, and Q, above include stand pipe tests, borehole tests, bail-down or slug tests using Hvorslev's Method and well pumping tests. Because of the wide variety of laboratory and field tests available, careful evaluation of the soil's make up and the selection of the appropriate testing method in these soil conditions is essential to achieving an accurate permeability rate. Since these tests usually concentrate on a specific area of the soil, more accurate results are obtained through testing over a greater area of soil.

Further guidance on methods and procedures for permeability testing can be found in the DEC's June 21, 1988 guidance policy entitled, "Permeability Testing Methods For Secondary Containment Systems" (http://www.dec.ny.gov/docs/remediation_hudson_pdf/tech5.pdf).

2.1.4 Chemical Compatibility Criteria

The purpose of compatibility testing is to ensure that the secondary containment system maintains its impermeability, chemical, and structural integrity during and after contact with petroleum product. The overriding consideration in the selection of material used for a secondary containment system liner is its chemical resistance to the contained liquid. Chemical resistance refers to the ability of the material to retain its physical strength and chemical barrier properties during and after direct contact with petroleum products. Chemical resistance should be considered separately from permeability or permeation resistance.

All materials used for lining a secondary containment system should be resistant to hydrocarbon mixtures. Liner materials should be resistant to tears and punctures, and be suitable for outdoor exposure. EPA Method 9090A, "Compatibility Test for Wastes and Membrane Liners" may be used to demonstrate compatibility.

2.1.4.1 Sealants and Tapes

Sealants and tape must be evaluated for chemical compatibility and weathering. In addition, sealants and tapes must be evaluated for their functionality. Where necessary, the test methods used for synthetic liners can be applied for sealants and tapes.

2.1.5 Volume Criteria

The DEC considers the minimum acceptable volume for a secondary containment system to be the greater of:

- (1) 110% of the largest tank in the containment area; or
- (2) the entire capacity of the largest single tank plus sufficient room for freeboard to contain precipitation. "Sufficient freeboard" is freeboard sufficient to contain precipitation from a 25-year storm event. This is partly based on the EPA and NFPA standards.

The National Fire Protection Association (NFPA) Standard No. 30 (2003), section 4.3.2.3.2 (B) states, "The volumetric capacity of a secondary containment system area shall not be less than the greatest amount of liquid that can be released from the largest tank within the secondary containment system area, assuming a full tank. To allow for volume occupied by tanks, the capacity of the secondary containment system area enclosing more than one tank shall be calculated after deducting the volume of the tanks, other than the largest tank, below the height of the containment area." DEC adopts this approach to determining the required volume of the containment area.

If tanks are interconnected and the connection does not have a valve that prevents uncontrolled flow of products from one tank to the other, the minimum acceptable volume of the secondary containment will be based on the combined volume of all interconnected tanks. If the combined volume of the interconnected tanks is less than the largest tank in the secondary containment system, the required volume is based upon the largest tank.

In the event that the volume of a secondary containment system does not meet the minimum requirement above, one of four things can be done. First, the current structure can be retrofitted by constructing higher dike walls according to NFPA 30 (2003) section 4.3.2.3.2 (B). Second, an alternative method to a diking structure can be used, such as impermeable impoundment pits or retention ponds. Third, the volume of the largest tank in the containment system can be reduced by physically removing the top course(s) of the tank shell as necessary. Fourth, if interconnected tanks include the largest tank in the secondary containment, and the connection does not have a valve that prevents uncontrolled flow of products from one tank to the other, the installation of a control valve between the tank connections or the removal of the tank may reduce the volume required.

2.2 Material Specific Inspections

2.2.1 Natural/Native Soil

2.2.1.1 Structural Integrity

A visual inspection of the containment floor and wall is required and should be performed as stated in section 2.1.1 "Visual Inspection" above. For the inspection of a natural/native containment system with ballast, for every 10,000 square feet of the containment area, 100 square feet of the ballast should be removed and the exposed area visually inspected (see section 2.1.1). In addition, the evaluations must include inspections and field testing specifically addressing the following typical failure modes:

- susceptibility to erosion and frost heave;
- shrinkage or desiccation;

- environmental damage (vegetation, rodents, worm holes, freeze/thaw, etc.); and
- physical damage from spills, equipment, vehicles, foot traffic, etc.

If the evaluation reveals deficiencies, or indicates that the containment system's ability to perform as expected in the event of a spill is questionable, the inspector must conduct appropriate physical tests of the elements of the containment system that are questionable.

2.2.1.2 Permeability

Permeability testing for this material is required at each 5-year inspection. Laboratory or field testing (see section 2.1.3) can be used to determine the permeability of natural soils, provided that the consistency of the deposit has been assured through a detailed geotechnical investigation. The DEC prefers and recommends obtaining representative field samples and measuring liner permeability in the laboratory using the flexible wall permeameter test. Undisturbed samples must be obtained using Shelby tubes or similar methods. The in-situ hydraulic conductivity of a natural soil can be estimated by measuring the conductivity using a conventional slug test where water is added to a cased hole within the geological deposit to be tested. The vertical, horizontal or mean hydraulic conductivity measured using a slug test is highly dependent on the flow characteristic at the bottom of the cased hole and other boundary conditions. The following test methods may be useful in performing this test: ASTM D1587 "Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes" and ASTM D2434 "Standard Test Method for Permeability of Granular Soils (Constant Head)."

The permeability of soil is greatly affected by its moisture content. It is prone to shrinkage, cracks, and desiccation when not properly maintained. Studies on compacted clay have shown increases in permeability by one to two orders of magnitude after being subjected to one freeze and thaw cycle in test conditions. Thus, adequate and proper maintenance of a soil liner is required to maintain its low permeability.

2.2.1.3 Chemical Compatibility

Generally, natural or native soil is chemically compatible with most liquids. There can be degradation if soil is in contact with ballast (cover materials) containing high levels of calcium or magnesium. Where this occurs a chemical compatibility assessment should be performed. Depending on the result of this assessment, the natural/native soil and or the ballast should be removed and replaced.

2.2.1.4 Volume

Volume requirements are not material specific. Please refer to section 2.1.5 for more information.

2.2.1.5 Sampling

The preparation, gathering and date of collection of soil samples for use in permeability testing have a significant effect on the integrity of the test results. Sample collection and preparation should be done using good engineering practices.

For every test, a minimum of one sample per 10,000 square feet should be collected, with not less than three samples per containment system and about 30% of the samples from the dike walls. Depending on the nature of the facility or project, the DEC may require more samples per area evaluated. For further

information on sampling, preservation and transportation of soil samples, refer to ASTM 1587 and ASTM 4220.

2.2.1.6 Inspection and Testing

In summary, the inspection and testing of natural/native secondary containment systems includes the following:

- visual inspection
- moisture content
- permeability

2.2.2 Clay Liners

2.2.2.1 Structural Integrity

A visual inspection of the containment floor and wall is required and should be performed as stated in section 2.1.1 “Visual Inspection” above. The evaluation of a clay liner system must include an integrity test or analysis using nationally recognized standards. In addition, the evaluation must include inspections and field testing specifically addressing the following typical failure modes:

- loss of hydration leading to shrinkage or desiccation;
- ion exchange creating calcium montmorillonite leading to increased permeability;
- physical damage from spills, equipment, vehicles, foot traffic, etc.; and
- environmental damage (vegetation, rodents, worm holes, and freeze/thaw, etc.).

If the evaluation reveals deficiencies, or indicates that the containment system’s ability to perform as expected in the event of a spill is questionable, the inspector must conduct appropriate physical test of the elements of the containment system that are questionable.

2.2.2.2 Permeability

Permeability testing for this material is required at each 5-year inspection. Laboratory or field testing (see section 2.1.3) can be used to determine the permeability of natural soils, provided that the consistency of the deposit has been assured through a detailed geotechnical investigation. The DEC prefers and recommends obtaining representative field samples and measuring liner permeability in the laboratory using the flexible wall permeameter test. Undisturbed samples must be obtained using Shelby tubes or similar methods. The in-situ hydraulic conductivity of clay can be estimated by measuring the conductivity using a conventional slug test whereby water is added to a cased hole within the geological deposit to be tested. The vertical, horizontal or mean hydraulic conductivity measured using a slug test is highly dependent on the flow characteristic at the bottom of the cased hole and other boundary conditions. The following test methods may be useful in performing this test: ASTM D1587 “Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes” and ASTM D2434 “Standard Test Method for Permeability of Granular Soils (Constant Head).”

The permeability of clay is greatly affected by its moisture content. It is prone to shrinkage, cracks, and desiccation when not properly maintained. Studies on compacted clay have shown increases in permeability by one to two orders of magnitude after being subjected to one freeze and thaw cycle in

test conditions. Thus, adequate and proper maintenance of a clay liner is required to maintain its low permeability.

2.2.2.3 Chemical Compatibility

Clay liners and most GCL (containing bentonite) are chemically compatible with most liquids, but can be degraded when in contact with high concentrations of salts, especially calcium or magnesium. Cover materials are usually required to keep the clay materials hydrated. Cover materials should not contain calcium or magnesium. Where cover materials contains high concentrations of salts, a chemical compatibility assessment should be performed. Depending on the result of this assessment, the clay liner and/or the ballast should be removed and replaced.

2.2.2.4 Volume

Volume requirements are not material specific, please refer to section 2.1.5 above for more information on this issue.

2.2.2.5 Sampling

The preparation, gathering and date of collection of soil samples for use in permeability testing have a significant effect on the integrity of the test results.

For every test, a minimum of one sample per 10,000 square feet should be collected, with no less than three samples per containment system and about 30% of the samples from the dike walls. Depending on the nature of the facility or project, the DEC may require more samples per area evaluated. For further information on sampling, preservation and transportation of soil samples, refer to ASTM 1587 and ASTM 4220.

2.2.2.6 Inspection and Testing

In summary, the inspection and testing of clay secondary containment system includes the following:

- visual inspection
- moisture content
- permeability

2.2.3 Geomembrane and Geosynthetic Clay Liner Inspection

2.2.3.1 Structural Integrity

The evaluation of a synthetic liner system must include a visual inspection. The inspections should be performed as stated in section 2.1.1 “Visual Inspection” above. The inspector must evaluate the level of hydration in geosynthetic clay liners. In addition, the evaluation must include visual inspections and field testing specifically addressing the following typical failure modes:

- defects at penetrations or at seams;
- UV degradation;
- thermal expansion and contraction;

- seam separation;
- separation of field assembled panel closure;
- tearing or puncture;
- environmental damage (extreme heat and cold, freeze-thaw, vegetation); and
- physical damage from spills, equipment, vehicles, foot traffic, etc.

For synthetic liners with ballast, ballast should be removed from a representative portion of the seams (e.g., a minimum of 500 linear feet or 1% of the seams, whichever is larger) and the seams tested and/or inspected for leaks. If the inspection reveals deficiencies or indicates that the containment system's ability to perform as expected in the event of a spill is questionable, then the inspector must conduct appropriate physical tests of the elements of the containment system that are questionable. At a minimum, geomembrane liners must be physically tested every fifteen years.

2.2.3.2 Permeability

Permeability testing for a GCL is required at each 5-year inspection. Geomembranes or geoliners are impervious non-porous materials, thus Darcy's law of flow through a porous medium is not valid here. However, when geomembranes are exposed to UV light and weathering, they lose their puncture strength, tear strength and tensile properties. Therefore, as long as geomembranes or geoliners meet the structural integrity requirements of section 2.2.3.1, they will be considered to have met the permeability standard.

2.2.3.3 Chemical Compatibility

The compatibility of geosynthetic liners with product stored must be verified using established method(s) by a nationally recognized organization such as the American Society of Testing and Materials, or the Geosynthetic Research Institute. Any laboratory which provides services for geosynthetic liner testing should be accredited by nationally recognized organization such as the Geosynthetic Accreditation Institute (GAI) or others which are acceptable to the DEC. Testing of this material can be done following the ASTM 5747, ASTM D 5322 or EPA Method 9090. In lieu of the facility owner conducting a test, the liner manufacturer's test or certification (that follows nationally recognized standards) may be acceptable to the DEC.

2.2.3.4 Volume

Volume requirements are not material specific, please refer to section 2.1.5 above for more information on this issue.

2.2.3.5 Sampling

The preparation, gathering and date of collection of liner samples for use in chemical compatibility testing have a significant effect on the integrity of the test results. Sample collection and preparation should be done using good engineering practices.

For every test, a minimum of one sample per 10,000 square feet should be collected, with not less than three samples per containment system and about 30% of the samples from the dike walls. Depending on the nature of the facility or project, the DEC may require more samples per area evaluated.

2.2.3.6 Inspection and Testing

In summary, the inspection and testing of synthetic and geosynthetic clay secondary containment systems includes the following:

- visual inspection
- structural integrity tests
- compatibility with material stored or manufacturer's certified and test
- compatibility with environment or manufacturer's certified and test

Table 8 provides recommended test methods.

Table 8: Recommended Geomembrane and Clay Liner Inspection Methods

Testing Parameters	Recommended Practice	Title
Sampling	ASTM D6072	Obtaining Samples of Geosynthetic Clay Liners
Leak Location on Exposed Geomembrane	ASTM D 7002	Standard Practice (SP) for Leak Location on Exposed Geomembranes Using the Water Puddle System
Locating Leaks in Geomembranes Covered with Water or Earth Materials	ASTM D 7007	SP for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials
Seams and joint test (Vacuum box test)	ASTM D4437	Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes
Construction Quality Assurance Guidelines	EPA/600/r-93/182	Quality Assurance and Quality Control for Waste Containment Facilities

2.2.4 Asphalt

2.2.4.1 Structural Integrity

The evaluation of an asphalt liner system must include an integrity test or analysis using nationally recognized standards. The inspections should be performed as stated in section 2.1.1 "Visual Inspection" above.

Light petroleum products degrade asphalt liners on contact. As a result of this incompatibility, asphalt liners generally are not used in secondary containment systems with tanks that store light petroleum products. For an asphalt liner to be acceptable in a secondary containment system with tanks that store light petroleum products, a sealant must be used to improve its resistance to degradation. For asphalt

liners with a sealant, asphalt provides a structural base to the containment system, while the sealant provides the required chemical resistivity to the system. The integrity of the system will depend on the integrity of both material sealant and asphalt. The typical failure modes of this system will be the same as the typical failure mode of the sealant, which are:

- cracks;
- pin holes;
- penetration;
- chemical compatibility of stored petroleum;
- UV degradation;
- long term durability of the sealant;
- environment damage (vegetation, moisture, rodents, etc.); and
- physical damage from spills, equipment, vehicles, foot traffic, etc.

If the evaluation reveals deficiencies, or indicates that the containment system's ability to perform as expected in the event of a spill is questionable, the inspector must conduct appropriate physical tests of the elements of the containment system that are questionable.

2.2.4.2 Permeability

Permeability testing for this material is required at each 5-year inspection. Asphalt is not chemically compatible with petroleum and as such its permeability will depend on the permeability of the asphalt sealant. The sealed asphalt must be tested to determine whether it meets acceptable standards (see Table 6 above).

2.2.4.3 Chemical Compatibility

An asphalt liner by itself, built in the same way as a roadway or parking lot, is not an acceptable secondary containment system liner because it is not compatible with petroleum products. However, a secondary containment system can be constructed with asphalt and a sealant such that it provides the required permeability and compatibility. Where an asphalt liner is constructed with a sealant, the compatibility with the stored product must be verified.

2.2.4.4 Volume

Volume requirements are not material specific, please refer to section 2.1.5 above for more information on this issue.

2.2.4.5 Sampling

The preparation, gathering and date of collection of liner samples for use in chemical compatibility testing have a significant effect on the integrity of the test results. Sample collection and preparation should be done using good engineering practices.

For every test, a minimum of one sample per 10,000 square feet should be collected, with not less than three samples per containment system and about 30% of the samples from the dike walls. Depending on the nature of the facility or project, the DEC may require more samples per area evaluated.

For further information on sampling, preservation and transportation of soil samples, refer to ASTM 1587 and ASTM 4220.

2.2.4.6 Inspection and Testing

In summary, the inspection and testing for sealed asphalt secondary containment system includes the following:

- visual inspection
- tests will be the same as sealant (section 2.1.4.1)

Permeability and chemical compatibility should be tested in accordance with nationally established methods.

Table 9: Recommended Asphalt Liner Test and Inspection Methods

Work	Method
Density	ASTM D 2041 or D 2726 or D 2950
Permeability	ASTM D 5084
Chemical Compatibility	ASTM D 5747 or EPA Method 9090

2.2.5 Concrete Dike

2.2.5.1 Structural Integrity

A visual inspection of the foundation, dike floor, and dike wall is required and should be performed as stated in (Visual Inspection) above. In addition, the evaluation must include inspections and field testing specifically addressing the following typical failure modes:

- cracks;
- sealants, caulks, water stops with stored petroleum;
- environmental damage (vegetation, impact of freeze-thaw); and
- physical damage from equipment, vehicles, etc.

If the evaluation reveals deficiencies, or indicates that the containment system's ability to perform as expected in the event of a spill is questionable, the inspector must conduct appropriate physical tests of the elements of the containment system that are questionable.

2.2.5.2 Permeability

A good quality concrete containment area has a very low permeability with a hydraulic conductivity of about 10^{-10} cm/s. However, leaks can occur from cracks, joints, and penetrations. Thus, adequate attention must be given to areas with the potential for cracks, such as joints or areas of the concrete containment that is prone to standing water.

2.2.5.3 Chemical Compatibility

Depending on the concrete mix, concrete dikes may need to be sealed with epoxy or other compatible sealants to increase their compatibility with petroleum and to reduce the potential for cracks. If concrete is sealed, the structural integrity and compatibility of the sealant must be evaluated.

2.2.5.4 Volume

Volume requirements are not material specific, please refer to section 2.1.5 above for more information on this issue.

2.2.5.5 Sampling

Generally, concrete dikes do not need sampling.

2.2.5.6 Inspection and Testing

In summary, the inspection and testing of concrete dike secondary containment systems includes the following:

- visual inspection
- permeability (especially for joint materials)
- where a sealant is used, a test for sealant integrity should be done

The DEC will accept tests performed following the “U.S. Army Corps of Engineers’ Engineer Manual (EM) No. 1110-2-2002, Chapter 2 for Evaluation of the Concrete in Concrete Structures,” and (ASTM C 597) “Standard Test Method for Pulse Velocity Through Concrete,” as appropriate.

2.2.6 Steel Dike

2.2.6.1 Structural Integrity

A visual inspection of the steel containment floor and wall is required and should be performed as stated in section 2.1.1, “Visual Inspection,” above. In general, visual documentation of coating (paint) degradation and subsequent corrosion degradation of the steel is of primary concern. The visual inspection would include the locations and size of rust stains, bulges, discoloration, release or leak traces, deferred or improper maintenance, evidence of foundation movement, settlement, or deterioration.

If the visual inspection reveals a structural integrity concern, another non-destructive test (NDT) method must be used to reevaluate the system and repairs performed accordingly. These NDTs may include magnetic particle, liquid penetrant, ultrasonic, pit gauge, etc. Where possible, the additional investigations should be performed by an ASNT certified professional. In rare cases, a radiographic examination may be necessary for investigation of critical structural welds.

Visual inspections and field testing specifically addressing the structural integrity and coating degradation must be performed. The field testing and documentation should include:

- pit depth measurement using a pit gauge; and
- documentation of the location and extent of corrosion.

For non-welded joints, a visual inspection of seals or caulking material, including documentation of chemical compatibility of the stored petroleum product with the secondary containment material, must be performed.

If the evaluation reveals deficiencies, or indicates that the containment system's ability to perform as expected in the event of a spill is questionable, the inspector must conduct appropriate physical tests of the elements of the containment system that are questionable.

2.2.6.2 Permeability

Steel is impervious to liquids for secondary containment purposes, thus Darcy's law of flow through a porous medium is not valid here. Pitting, corrosion, and seal failure can lead to leaks. Adequate testing of all typical failure modes should be performed.

2.2.6.3 Chemical Compatibility

Generally, steel dikes are chemically compatible with petroleum.

2.2.6.4 Volume

Volume requirements are not material specific, please refer to section 2.1.5 above for more information on this issue.

2.2.6.5 Sampling

Generally, steel dikes do not need sampling. However, sampling may be necessary where steel is used in combination with other material and sealants or tapes are used in the joint. Where the chemical compatibility of the sealant is unknown, samples of the sealant or tapes must be taken to confirm the chemical compatibility. In this instance, a minimum of one sample per 1,000 linear feet should be collected, with no less than three samples per containment system and about 30% of the samples from the dike walls. Depending on the nature of the facility or project, the DEC may require more samples per area evaluated.

2.2.6.6 Inspection and Testing

In summary, the inspection and testing of steel secondary containment systems includes the following:

- visual inspection
- corrosion rate: report should include the expected life of the containment
- average thickness of the steel material
- integrity of all seams

2.3 Submittal Requirements

The proper design and construction of a secondary containment system is the owner's responsibility as is the proper maintenance, inspection and testing of the system. Discussed below are the required elements of a five year certification report. The required information shall be submitted in the form of a report package within 30 days of the expiration of the five-year period. A report package shall be a complete report containing all recommendations for further action, work plan for implementing the recommendations, and all the material mentioned below. Work plans for the implementation of the recommendations must be approved by the DEC before their implementation.

2.3.1 Report Package Organization

- Executive Summary
- N.Y.S.P.E Certification
- Site Description
- Visual Inspection Assessment
- System Integrity Assessment
- System Permeability
- System Compatibility
- Tank and Containment System Volume
- Conclusions and Recommendation

2.3.2 NYSPE Certification/Management Review of Containment System

A professional engineer (P.E.), licensed and registered in New York State by the New York State Education Department, must verify and certify that:

- the secondary containment system has been evaluated in accordance with DER-17;
- all engineering evaluations and repair was done under his/her supervision;
- the system was designed and constructed in accordance with good engineering practices;
- any repairs were completed in accordance with this document;
- the system meets or exceeds applicable requirements; and
- the system is suitable for continued use.

2.3.3 Site Description

A general description of the site including the immediate surrounding should be included.

2.3.4 Visual Inspections

All visual inspection reports should be submitted, consistent with the format of section 2.1.5, "Visual Inspection," above.

2.3.5 System Integrity Assessment

System assessment following the guideline of section 2.2, "Material Specific Inspections" must be included.

2.3.6 System Permeability

A demonstration that existing, upgraded, or new secondary containment systems meet or exceed the permeability requirements stated in Table 6 above will be accepted as evidence of compliance with the permeability requirement of section 613.3(c)(6).

2.3.7 System Compatibility

The DEC will accept as evidence of chemical compatibility either a liner manufacturer's certification of chemical compatibility of the liner and the specific product stored using the method(s) identified in this guidance document or other appropriate consensus standard.

2.3.8 Tank and Containment System Volume

Information for all tanks in the secondary containment area should be stated in the report, including tank volume, and any tank-to-tank interconnections. Calculations must be provided, and such calculations must show the ability of the secondary containment system to meet the requirements of section "Volume Criteria" 2.1.5 above. A complete description of the volume of the secondary containment area is required in each of the following cases:

1. At the first 5-year certification of the secondary containment system if reliable calculations do not already exist, or
2. If there has been substantial modification affecting the volume of the secondary containment system; or
3. If, for any other reason, a recalculation of the secondary containment system volume is necessary.

The description should include the following (maps may be submitted as a single document or separately as individual documents):

- site map;
- secondary containment system map; and
- secondary containment system volume calculation.

2.3.9 Conclusions and Recommendation

A summary of the evaluation of the system, including all recommendations for further action should be included.

2.4 Deficiencies and Repairs

2.4.1 Containment Deficiencies

If the evaluation of a secondary containment system shows that the system does not meet minimum requirements set forth in this document, an engineering plan describing how the existing system will be

improved must be submitted to the DEC. This plan:

- shall be submitted along with the report package;
- must be certified by a Professional Engineer, who is licensed and registered with the New York State Education Department;
- should include: composition and permeability of the existing soil/liner; methodology that will be used to upgrade the secondary containment system; specifications of the material to be used; procedures for installation; and proposed permeability of the resulting containment system; and
- must be approved by the DEC before its implementation.

All deficiencies and recommendations must be addressed within 60 days from the date of the plan approval, and a report submitted to the DEC.

3 Additional References

Below is a list of institutes that provide Standards/Testing/Recommended Practices.

1. **American Association of State Highway and Transportation Officials (AASHTO)**
444 North Capital St. N.W. , Suite 249, Washington, DC 20001, Phone: (202) 624-5800
2. **American Concrete Institute (ACI)**
38800 Country Club Drive, Farmington Hills, Michigan 48331, Phone: (248) 848-3700
3. **American Petroleum Institute (API)**
1220 L Street, N.W., Washington, DC 20005, Phone: (202) 682-8000
4. **Asphalt Institute (AI)**
2696 Research Park Drive, Lexington, KY 40511-8480, Phone: (859) 288-4960
5. **American Society of Civil Engineers (ASCE)**
1801 Alexander Bell Drive, Reston, Virginia 20191, Phone: (703) 295-63000
6. **American Society of Testing and Materials (ASTM)**
100 Barr Harbor Drive, West Conshohocken, PA 19428, Phone: (610) 832-9585
7. **Geosynthetic Accreditation Institute (GAI)**
One of five individual institutes under the auspices of **Geosynthetic Institute (GSI)**,
475 Kedron Ave., Folsom, PA 19033, Phone: (610) 522-8440
8. **Geosynthetic Research Institute (GRI)**
One of five individual institutes under the auspices of **Geosynthetic Institute (GSI)**,
475 Kedron Ave., Folsom, PA 19033, Phone: (610) 522-8440

9. **International Concrete Repair Institute (ICRI)**
3166 S. River Road, Suite 132, Des Plaines, IL 60018, Phone: (847) 827-0830
10. **National Association of Corrosion Engineers (NACE)**
1440 South Creek Drive, Houston, TX 77084, Phone: (281) 228-6200 or 1-800-797-6223
11. **National Asphalt Pavement Association Research and Education Foundation (NAPA-REF)**
5100 Forbes Blvd., Lanham, MD 20706, Phone: (888) 468-6499
12. **Society for Protective Coatings (SSPC)**
40 24th Street, 6th Floor, Pittsburgh, PA 15222, Phone: (412) 281-2331 or (877) 281-7772
13. **Steel Tank Institute (STI)** 570 Oakwood Road, Lake Zurich, IL 60047, Phone: (847) 438-8265
14. **US Army Corps of Engineers (USACE)** USACE Publication Depot, 2803 52nd Ave., Hyattsville, MD 20781, Phone: (301) 394-0081/0082/0083.
15. **US Environmental Protection Agency (USEPA)**
1200 Pennsylvania Svc., N.W. Washington, DC 20460, Phone: (202) 272-0167