SUBMISSION INSTRUCTION NO. 2 (SI2)

MODULE III, IV AND V LANDFILL DESIGN REPORT

I. GENERAL. [§§ 250.B., 260.B., or 270.B., and 520.A. and 520.B., 9 VAC 20-80-10] Submit three copies of all plans and reports required by the regulations and listed in the instructions shown below. The design must be prepared and certified by an engineer registered to practice professional engineering in the Commonwealth. The title sheet of the design plans shall include the following information:

- Project title;
- Preparer of the plans;
- The organization for which the plans were prepared; and
- Location map of the site and the area to be served.

A discussion of all calculations shall be included in the Design Report and all calculations shall be included as Attachment 2 to the report. Instructions for calculations can be found in Part III of *Submission Instruction 2*. In addition, design plans (Attachment 1), a copy of the Part A approval with maps (Attachment 3), the gas management plan (Attachment 4), the technical specifications (Attachment 5) and construction quality assurance plan (Attachment 6) are also provided as attachments. Technical specifications and construction quality assurance are discussed in Parts IV and V of *Submission Instruction 2* Please see *Submission Instruction 1* for details regarding the recommended format of the submission.

A. General Site Plans. [§§ 520.A.1., 9 VAC 20-80-10] 3 full sets of design plans for the facility will be provided with the submission. Once plans have been reviewed and approved reduced drawings will be provided to be3 included in the facility permit. Furnish the following general site plans and provide a list of drawings that have been certified by a professional engineer under this section in the Design Report:

1. Existing Site Conditions. [§ 520.A.1b, 9 VAC 20-80-10] Show conditions existing at the site prior to the development.

2. Base Grade Plan. [§ 520.A.1c, 9 VAC 20-80-10] Show site base grades or appearance of the site if it were excavated in its entirety to base elevation, before installation of any engineering modifications.

3. Modification Plans. [§ 520.A.1d, 9 VAC 20-80-10] Show engineering modifications indicating the appearance of the site after installation of all engineering modifications. Include typical cross sections.

4. Phasing Plans. [§§ 520.A.1f and 520.A.1h, 9 VAC 20-80-10] Show plan and cross-section views of the progression of site development through time. At a minimum, a separate plan shall be provided for initial site preparations and for each major phase or new area where substantial site preparation must be performed.

5. Cross Sections. [§ 520.A.1h, 9 VAC 20-80-10]. Site cross sections shall be drawn perpendicular and parallel to the site baseline at a maximum distance of 500 feet between cross sections and at points of grade break and construction features. The location of the cross sections shall be shown on the appropriate plan sheets and the sections labeled using the site grid system.

6. Final Site Topography. [§ 520.A.1.e, 9 VAC 20-80-10]. Show final site topography indicating the appearance of the site and final contours of the site at closure, including any detail drawings necessary to prepare the site for long term care.

B. General Facility Information. [§ 520.B.1. and 520.B.2., 9 VAC 20-80-10] Submit the following as a part of the introduction to the Design Report :

- Project title;
- Engineering consultants;
- Site owner, permittee and operator;
- Proposed permitted acreage (specified by construction phases or cells, if applicable);
- Site life and capacity;
- Site monitoring plan sheet;
- Municipalities, industries and collection and transportation agencies served;
- Waste types and quantities to be processed;
- Any exceptions to the regulations; and
- Part A approvals, including maps.

C. Facility Design. Show on the General Site Plans and discuss in the Design Report the following:

1. Floodplain. [§ 260.A.1., and 270.A.1., 9 VAC 20-80-10]. The 100-year floodplain should be indicated on the existing site conditions sheets and the engineering modification plan sheets at a minimum. A statement should be provided indicating that the facility is not in a floodplain if applicable. For facilities within 100-year floodplain, the Design Report should include discussions to:

- Describe how the facility is designed, constructed, operated and maintained to prevent washout of any solid waste during the flood;
- Provide a structural or other engineering study showing how the design of the units and the flood-proofing and protection devices at the facility will prevent washout; and
- Provide a study showing that the flood-proofing structures will not affect the flow of the flood waters.

2. Site Access. [§§ 250.B.1., 250.B.2., 260.B.1., 260.B.2., 270.B.1., 270.B.2., 520.A.1h, 520.A.1i, 520.A.1j, and 520.B.2., 9 VAC 20-80-10] Show the plans and cross sections of all permanent and temporary fencing and barriers and describe how the site access will be controlled to limit access and to prevent illegal disposal. Show plans and cross sections of the access roads to the gate and roads and ramps on the site perimeter and within the active fill areas. Discuss the traffic flow pattern and specify the access road condition.

3. Shelter. [§§ 250.B.3., 250.B.5., 260.B.3., 260.B.5., 270.B.3., and 270.B.5., 9 VAC 20-80-10] Adequate shelter for operating personnel is required. Show the location of the personnel shelter and the sanitary facilities. Describe their adequacy during inclement weather; also describe the provisions for heat, lighting, and communications.

4. Aesthetics. [§§ 250.B.4., 260.B.4., or 270.B.4., and 520.A.1j(11), 9 VAC 20-80-10] Show natural or artificial screening of the operation areas, *supported by line-of-sight studies*. Describe how noise will be attenuated to no more than 80 dBA at the facility boundary. Describe also the plan for the long-term use of the property.

5. Location of Cells. [§§ 250.B.2., 260.B.13., or 260.B.15., and 520.A.1h, 520.A.1i, and 520.A.1j, 9 VAC 20-80-10] Show the location and the limits of all disposal cells. Include severe weather and special waste disposal areas. In case of construction/demolition/debris (CDD) landfills, show the location of the unlined area for stumps, if any. Describe in the report how the separation from the groundwater will be achieved for all unlined areas.

6. Benchmarks. [§§ 250.B.16., 260.B.10, 270.B.9., and 520.A.1j(1), 9 VAC 20-80-10] Show the survey grid with base lines and the location of the site benchmarks. Indicate in the design report or on the plans the benchmark information. Permanent concrete monuments that are separate from other facility features must be provided.

6. Borrow and Stockpile Areas. [§ 520.A.1j(7) and 520.A.1j(8), 9 VAC 20-80-10] Show all borrow and stockpile areas for liner and gas venting materials, berms, roadway construction, daily and final cover. The amount of material available on site must be provided. If the material is to be used for final cover, the types and engineering properties of the soil present must be determined and presented in the construction specifications required in Part IV of SI 2.

D. Site Conditions. [§ 520.B.2., 9 VAC 20-80-10] List and discuss the conditions of site development as stated in the Department's determination of site feasibility and the measures taken to meet the conditions. Attach the Part A approval letter as Attachment 3 of the Design Report.

II. SITE DESIGN

A. Regulatory Requirements

1. Sanitary Landfills. [§§ 250.B.9. and 520.A.1h, and 520.B.2., 9 VAC 20-80-10] New units and lateral expansions of existing units must either comply with the design standard or petition for an alternate liner design standard. The design standard is a composite liner comprised of two feet of soil with a hydraulic conductivity of $1x10^{-7}$ cm/sec, overlain by a geomembrane. The geomembrane must be in direct and uniform contact with the soil liner. The requirements for an alternate liner design standard must be provided in accordance with the requirements of 9 VAC 20-80-780. A variance is required for alternate liner design. In the Design Report, provide a description of the proposed liner system cross section and provide a statement indicating that the design meets the requirements of the regulations or the conditions of the alternate liner variance. Attach any alternate liner variance as Attachment 7 of the Design Report.

2. Other landfills. [§ 260.B.14. or 270.B.14. and §§ 520.B.2., 9 VAC 20-80-10] CDD and industrial waste landfills must be underlain by one of the low-hydraulic conductivity liners listed in the regulations: one foot of compacted soil with hydraulic conductivity of no greater than $1x10^{-7}$ cm/sec, geomembrane, augmented soil liner, or other listed liners. In the Design Report, provide a description of the proposed liner system cross section and provide a statement indicating that the design meets the requirements of the regulations.

B. Landfill Unit Design. [§ 520A.1.d. and 520.A.1.h.] Show the design plans and cross sections of the disposal unit including the liners and leachate collection and removal system. Discuss in the Design Report, the following:

1. Liner Foundation.

a. Design Description. Describe the liner foundation design and materials of construction provided in the construction specifications. Discuss the design of the foundation including the capability of the foundation to support any expected static and dynamic loading, foundation consolidation, differential settlement, bearing capacity and foundation stability. Support the discussion with the results of the engineering analysis performed on the liner foundation materials.

b. Location Relative to High Water Table. Discuss the location of the seasonal high water table relative to the liner system. Provide data showing fluctuations in the depth to the water and the location of the seasonal high water table.

2. Liner System. Provide a description of the liner system. Describe the type of liner, its material, and, for synthetics, the manufacturer's name.

a. Soil Liners. Describe ranges of physical characteristics for the soil liners required in the construction specifications including hydraulic conductivity, soil density moisture content relationships, maximum clod size, and gradation. Discuss the test methods that will be used to measure the characteristics.[1] Include the test methods that will be used to measure hydraulic conductivity in the laboratory[2] and in the field.[3] Note that the

[1] Grain size distribution (ASTM D-422); Atterberg limits (ASTM D-4318); compaction curves depicting moisture-density relationships using standard or modified Proctor (ASTM D-698 or ASTM D-1557), whichever is appropriate for the compaction equipment used.

[2] Acceptable methods: EPA Method 9100, SW-846; U.S.Army Corps of Engineers Manual 1110-21906 (1970); ASTM D-5084 *"Measurement of Hydraulic Conductivity of Saturated Porous Materials Using Flexible Wall Permeameter."*

[3] Field testing methods: ASTM 6391-99 *"Standard Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials using Two Stages of Infiltration from a Borehole"* (in-situ test, known as 'Boutwell' method), porous probes, infiltrometers, and underdrains.

regulations require insitu testing of liner materials. Describe the use of the selected field testing method.

b. Geomembrane Liners. Describe the polymer type, fabric reinforcement, thickness and texture (e.g., smooth or textured for HDPE) required in the construction specifications. Discuss the capability of the geomembrane liner to resist physical and mechanical stresses. Support the discussion with the results of the engineering analysis performed on the geomembrane liner including discussions of:

- Differential settlement in the foundation soils;
- Strain requirements at the anchor trench;
- Strain requirements over long, steep side slopes;
- Equipment traffic during installation;
- Thermal effects during construction and operation;
- Long-term stresses resulting from the placement of wastes;
- The ability of a geomembrane to support its own weight on the side slopes;
- The ability of a geomembrane to withstand down-dragging during and after waste placement;
- The best anchorage configuration for the geomembrane; and
- The stability of a soil cover/drainage material on top of a geomembrane.
- Liner strength requirements with respect to:

  -Internal and external pressure gradients;

  -Stresses resulting from settlement, compression or uplift;

  -Climatic conditions (freeze-thaw stress);

  -Installation stresses (with particular attention to side slopes); and

  -Operating stresses (with particular attention to side slopes).

Describe how the liner required under the construction specifications exceeds the calculated minimum strength requirements.

c. Coverage. Describe how the liner will be installed to cover all surrounding earth likely to be in contact with the waste or leachate.

d. Prevention of Exposure. Discuss the properties of the liner required in the construction specifications and indicate the effects of the exposure of the liner to wind or sunlight and any measures necessary to protect the liner from damage or degradation.

3. Leachate Collection and Control. [§§ 250.B.11., 250.B.12., 260.B.8., 270.B.7., 270.B.11., 270.B.15., 290., 520.A.1g, 520.A.1h, 520.A.1i, and 520.A.1j, 9 VAC 20-80-10] Leachate is generally collected from the landfill through sand drainage layers, synthetic drainage nets or granular drainage layers in combination with perforated plastic collection pipes, and removed through sumps or gravity drain carrier pipes. Each leachate collection system (LCS) consists of the following components:[4]

[4] U.S. EPA, "Guide to Technical Resources for the Design of Land Disposal Facilities," EPA/625/6-88/018; U.S. EPA; Risk Reduction Engineering Laboratory; Center for Environmental Research Information; Cincinnati, Ohio 45268 (1988)

- A low-permeability liner;
- A high-permeability drainage layer constructed of either natural granular materials (sand and gravel) or synthetic drainage material (e.g., geonet). The drainage layer is placed directly on the liner, or on protective bedding layer (e.g., geofabric) directly overlying the liner;
- Perforated leachate collection pipes within the high-permeability drainage layer to collect leachate and carry it rapidly to a sump or collection header pipe;
- A protective filter layer is some times provided over the high-permeability drainage material which may prevent physical clogging of the drainage material by fine grained particles; and
- Leachate collection sumps or header pipe system where leachate can be removed.

a. LCS Description. Describe the leachate collection system and materials of construction provided in the construction specifications. Describe the network to include the layout and spacing[5] of the pipe collection system.

b. LCS Design. Discuss the capability of the LCS to maintain less than 12" of leachate above the liner system. Discuss each component of the LCS provided in the specifications including the drainage layer, pipe, sumps, risers, pumps etc. and the ability of each component to support expected loads and handle anticipated flows. Support the discussion with the results of the engineering analysis performed on the LCS componenets considering the stuctural performance as well a the ability to control anticipated flow..

4. Leachate Removal System. Show the design of sumps, force main, side-wall risers, or manifolds and the type and sizing of any pumps, if used. If portable pumps are to be used, specify the schedule to move a pump from one sump to another in the operating plan. If gravity method is used for leachate removal, show pipe penetrations through the geomembrane and liner system and describe the construction of the penetration.

5. Stability. The design report shall discuss the stability of the individual leachate collection system components placed on geomembrane covered slopes and shall list the factors of safety (FS) for these components.[6]

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[5] The pipe spacing may be determined by the Mound Model as shown in: U.S. EPA, "Seminar Publication - Requirements for Hazardous Waste Landfill Design, Construction and Closure," EPA/625/4-89/022; U.S. EPA; Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268 (1989).

[6] A method for calculating FS against sliding for soils placed on a sloped geomembrane surface is provided in Koerner, Robert M., "Designing with Geosynthetics," 2nd Edition; Prentice Hall; Englewood-Cliffs, New Jersey 07632 (1990).

6. Leachate Treatment or Disposal. Describe the leachate treatment or disposal method that will be used.

C. Leakage Monitoring System. [§ 260.B.14e(3) or 270.B.14e(3), 9 VAC 20-80-10] For landfills equipped with double liners, describe the design of the leak detection system and the materials of construction. Describe the layout and spacing of the pipe network.

D. Collection and Storage Units. [§§ 250.B.6.c, 250.B.11., 250.B.12., 260.A.3., 260.B.8., 260.C.14., 270.B.6.c, 270.B.7., 270.B.13., 290.C., 520.A.1i and 520.A.1j, 9 VAC 20-80-10] Show and describe the design of collection and storage facilities associated with LCS, force main, run-on and run-off systems. The design may include berms, ditches, pumps, sumps, tanks, and surface impoundments. Include the description of the required volumes and the methods of removal and disposal. Support the discussion with the results of appropriate calculations

E. Run-on Control System. [§§ 250.B.6.a, 260.B.6., 270.B.6., and 270.B.13., 520.A.1h, 520.A.1i, and 520.A.1j, 9 VAC 20-80-10] Show plan and cross section views and describe the system that will be used to prevent run-on onto the active portions of the landfill.

F. Run-off Control System. [§§ 250.B.6b., 260.B.6., 270.B.6., 520.A.1h, 520.A.1i, and 520.A.1j, 9 VAC 20-80-10] Show and describe the run-off control system to be used to collect and control run-off from active portions of the landfill.

III. Design Calculations. Design calculations will be provided that support the design discusions provided in the facility Design Report. Design calulations will be presented in Appendix 2 of the Design Report.

A. Landfill Liner Foundation. Engineering analyses of the landfill foundation should be provided which are based on the data gathered through subsurface exploration and laboratory testing programs. Identify sources of data used in the design calculations and any assumptions used. Provide the following information:

(1) Settlement Potential. Provide calculated estimates of total and differential settlement, including immediate settlement, and primary and secondary consolidation. Stresses imposed by liners, wastes and equipment should be considered.

(2) Bearing Capacity and Stability. Determine the capability of the foundation to support any expected static and dynamic loading. Provide calculated estimates of the bearing capacity and stability of foundation, demonstrating that allowable bearing capacity will not be exceeded.

(3) Bottom Heave or Blow-out. Provide calculated estimates of the potential for bottom heave or blow-out due to unequal hydrostatic or gas pressures.

(4) Construction and Operational Loading. Demonstrate that the foundation is capable of providing adequate support for construction and operating equipment.

(5) Laboratory Data. Attach the results from sufficient index testing to classify the site materials. Other lab test data should be provided to evaluate the engineering properties of the foundation materials, particularly for strength, hydraulic conductivity, compressibility, and other important design parameters. This information should be provided in Appendix 1 of the Design Calculations.

(6) Subsurface Exploration Data. Attach supporting information, which may include:

- Test borings;
- Test pits or trenches;
- In-situ tests; and
- Geophysical exploration methods.

The information should be provided in Appendix 2 of the Design Calculations.

B. Landfill Liner

1. Soil Liners

a. Hydraulic Conductivity. Determine the relationship of water content, density and hydraulic conductivity for the soil to be used.

2. Geomembrane liner

a. Physical Stresses. Show calculations of physical stresses to include the following:

- Differential settlement in the foundation soils;
- Strain requirements at the anchor trench; and
- Strain requirements over long, steep side slopes.

b. Integrity Under Mechanical Stresses. Provide calculations of the short-term stresses from equipment traffic during installation and the early phases of operation. The design basis for equipment traffic should be the heaviest piece of equipment that may be used during construction or operation activities. Provide calculations of stresses due to thermal effects during construction and operation. Evaluate the long-term stresses resulting from the placement of wastes and from subsequent differential settlement of the subgrade.

c. Friction Factors. Demonstrate that there will be adequate friction between the components of the liner system particularly the soil subgrade and the geomembrane, so that slippage and sloughing do not occur on the slopes of the unit. Specifically, the foundation slopes and the subgrade materials must be considered in design equations to evaluate:

- The ability of a geomembrane to support its own weight on the side slopes;
- The ability of a geomembrane to withstand down-dragging during and after waste placement;
- The best anchorage configuration for the geomembrane; and
- The stability of a soil cover/drainage material on top of a geomembrane.

d. Liner Strength Requirements. Provide calculations defining the minimum strength requirement for liners considering:

- Internal and external pressure gradients;
- Stresses resulting from settlement, compression or uplift;
- Climatic conditions (freeze-thaw stress);
- Installation stresses (with particular attention to side slopes); and
- Operating stresses (with particular attention to side slopes).

C. Leachate Collection and Removal System

1. Leachate Flow. [§ 290.A.1.] Estimate the quality and quantity of leachate to be generated annually by each unit, based on generally accepted methods for projection of leachate flow.[7] The estimate shall include the 30-day volume and average flow rate for each month of the year. Separately show anticipated leachate generation at the end of 5-year increments for 20 years or until closure. For existing facilities, include the current generation rate. For planning purposes, the suggested storage volume for on-site storage of leachate is seven (7) times the peak daily value from a help model simulation with one lift of waste. Describe assumptions, data sources and methods used to make the calculations. The critical design condition for meeting the 12-inch criterion for leachate above the landfill liner can therefore be expected during the operating life.

2. Drainage Layer Design. [§§ 290.A.2. and 290.B.] The leachate collection and removal system (LCRS) shall be designed and placed to prevent failure of the liner, to filter and prevent migration of fines to the drainage layer, and to ensure that no more than 12 inches of leachate may accumulate over the liner at its lowest point excluding sumps and manifolds. Show plan and cross section views and describe the design features of the LCRS.

(a) Soil Drainage Layer

(1) Bearing Strength. Demonstrate that the drainage layer will have sufficient bearing strength to support expected loads.

(2) Slope Stability. If the landfill is designed on moderately to steeply (greater than 15%) sloping grades, include calculations demonstrating that the selected granular drainage materials will be stable on the most critical (e.g., usually the steepest) slope in the design. The calculations and assumptions shall be shown, especially the friction angles between all material interfaces, and supported by laboratory and/or field testing.

(b) Geosynthetic Drainage Layers. Geosynthetic drainage nets (geonets *and geocomposites*) may be substituted for the granular layers of the LCRS on the sidewalls of the landfill cells. A geonet can be considered for bottom drainage use in CDD and industrial landfills. Filter materials are sometimes used above geosynthetic drainage layer. These materials can experience problems with creep, intrusion, biological clogging etc.

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[7] The Hydraulic Evaluation of Landfill Performance (HELP) Model

(1) Transmissivity. If a geonet is used in place of a granular drainage layer, it must provide the same level of performance (maintaining less than 12 inches of leachate head above the liner). Show the calculation used to compute the capacity of a geonet and filter system. The transmissivity of a geonet can be reduced entirely by intrusion of the fine textured materials. A protective geotextile between this material and geonet is sometimes used to help alleviate this concern. Show the results of the laboratory transmissivity tests performed under loads, and configurations that closely replicate the actual field conditions. It is important that the transmissivity value used in the leachate collection system design calculations be selected based upon those loaded conditions.[8]

(2) Creep. Show that creep or intrusion of fines will be prevented. Specify minimum transmissivity under expected operating (dynamic) and completion (static) loads. The specifications for thickness and type of materials shall be identified on the drawings and shall be consistent with the design calculations.

(3) Side Slopes. Show the friction factors against sliding for geotextiles, geonets, and geomembranes. Manufacturers' data may be used, but shall be supported by the results of actual tests using site materials. Show all sliding stability calculations.

3. Protection of Drainage Systems. [§ 290.B.12.] The openings in drainage materials, whether holes in pipes, voids in gravel, or apertures in geonets, are sometimes protected against clogging due to accumulation of fine (silt-sized) materials. An intermediate material, between the waste and drainage layer, having smaller openings than those of the drainage material, can be used as a filter. Sand or geotextiles may be used as filter material. The soil filter layer may be the uppermost layer of the LCRS; however, optionally, a buffer layer may be included to protect the filter layer from damage due to traffic. This buffer layer may be general fill, as long as it is no finer than the soil used in the filter layer. If leachate recirculation is to be included, care must be taken to ensure that the permeability of the buffer is sufficiently high. If geotextiles are used on a slope, they should be secured in an anchor trench similar to those for geomembranes or geonets. Demonstrate that the use of graded material or filter fabric system design will prevent physical clogging (sedimentation) throughout the active life of the landfill and the post-closure care period. To prevent chemical and biological clogging, show the design of a cleaning system to include:

- A minimum of six-inch diameter pipes to facilitate cleaning;

[8] Use ASTM D-4716 to evaluate the transmissivity of the geonets.

- A slope sufficient for self-cleaning;[9]
- Access located at major pipe intersections or bends to allow for inspections and cleaning; and
- Valves, ports, or other appurtenances to introduce biocides and/or cleaning solutions.

a. Soil Filter Layer. Show how the design and material specifications of the filter layer will allow adequate flow of liquids through it, will provide adequate retention of fines, and evaluate the possibility of long-term clogging of the filter. Include estimates of particle size distribution of the drainage system and of the invading materials. Describe the thickness of the filter layer, the method of placement, and the dimensions of any envelope around the piping system.

b. Geotextile Filter Layer. Geotextile filter design parallels sand filter design with some modifications. The most important specifications are those of hydraulic conductivity and retention. In practice, it should be noted that the use of geotextiles as filter material has resulted in problems with clogging due to biological growth on the geotextile.

4. Leachate Collection Pipe. The design of perforated collection pipes should consider the following factors:

- The required flow using known percolation impingement rates and pipe spacing;
- Pipe size using the design leachate flow (*see* § V.A.1. of these instructions); and
- The structural strength of the pipe.

a. Sizing. Demonstrate that pipe and pipe perforation sizes are sufficient to allow free leachate access to the drainage system yet avoid clogging of the perforations and pipes by the drainage media. Show all calculations.

b. Piping Strength. The component that is most vulnerable to strength failure is the drainage layer piping. Demonstrate that any piping used will have sufficient strength to prevent collapse from anticipated static and dynamic loads. Pipe strength calculations should include resistance to wall crushing, pipe deflection, and critical buckling pressure.

5. Run-on Control System. [§§ 250.B.6.a, 260.B.6., 270.B.6., and 270.B.13., 520.A.1h,

[9] Generally, flow velocities should be in the vicinity of two feet per second.

520.A.1i, and 520.A.1j, 9 VAC 20-80-10]

a. Peak Flow. Calculate the peak surface flow expected to result from a 25-year design storm. Describe the data sources and methods used to make the peak flow calculations. For conveyance system components, a storm event of high intensity and short duration should be used. Shorter duration storms are more intense and are acceptable for peak flow design.

b. Design and Performance. Describe the run-on control system design. Demonstrate that the designed system will prevent run-on from reaching active portions of the landfill.

6. Run-off Control System. [§§ 250.B.6b., 260.B.6., 270.B.6., 520.A.1h, 520.A.1i, and 520.A.1j, 9 VAC 20-80-10]

a. Design Volume. Identify the total run-off volume expected to result from a 24-hour 25-year storm.[10] Describe data sources and methods used to make the calculations.

b. Design and Performance. Describe the run-off collection and control system design. Demonstrate that the system has sufficient capacity to collect and hold the total run-off volume. Note that a storm of shorter duration and greater intensity represents a more conservative design basis for the collection system components.

7. Leakage Monitoring System. [§ 260.B.14e(3) or 270.B.14e(3), 9 VAC 20-80-10]

a. Grading. Demonstrate that the leak detection points are appropriately located. Show that the drainage media in which the leakage monitoring system operates is appropriately graded to assure that leakage at any point in the liner system could be detected.

b. Pipe Network. If a pipe network is used to collect leakage, show calculations for the spacing of the pipe network.

c. Piping Strength. Demonstrate that any piping used between the liners will have sufficient strength to prevent collapse from anticipated static and dynamic loadings.

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[10] Information may be obtained from Technical Paper 40, *Rainfall Frequency Atlas of the Unites States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*, U.S. Department of Commerce.

d. Sizing. Demonstrate that pipe and pipe perforation sizes are sufficient to allow free liquid access to the drainage system yet avoid clogging of the perforations and pipes by the drainage media.

e. Drainage Media. Demonstrate sufficient gradation of drainage media and filter materials to allow free liquid access to LMS. Demonstrate that drainage media thickness and hydraulic conductivity will be sufficient to promote drainage.

f. Monitoring. Demonstrate that the LMS will provide timely detection of liquids entering the space between the liners.

IV. Construction Specifications. [§ 520.B.3a, 9 VAC 20-80-10] Present the specifications for site construction and operation. The specifications shall include, as a minimum, the following information:

- Clearing and grubbing;
- Topsoil stripping;
- All excavations;
- Berm construction, if applicable;
- Drainage control structures;
- Leachate collection system;
- All roads and ramps;
- Screening and fencing;
- Groundwater monitoring; and
- Other special features.

A. Liners.

1. Soil Liners

a. Construction. Specify the method to be used to compact soil to achieve minimum hydraulic conductivity. Specify the range of moisture contents and corresponding soil densities that will be considered appropriate to achieve the required hydraulic conductivity. Describe the following parameters:

- Lift thickness;
- Full scale or segmented placing;
- Equipment used (*compaction and rolling machinery*);
- Estimated number of equipment passes;
- Scarification between lifts;
- Control of soil water content;
- Limits on clod sizes; and
- Special considerations for tie-ins to existing liners.

b. Amended Soil Liners. In addition to the above requirements, when soil additives are to be used specify the type of additive, the concentration to be added, and the methods that will be used to mix and spread the material.

c. Placement on Slopes. Describe the method that will be used to place the liner on slopes. If sidewalls are compacted horizontally, describe how the edges will be tied in with the bottom of the soil liner.

d. Liner Thickness. For soil liners, describe how vertical and horizontal cracks and other imperfections will be detected and prevented. Describe the lift thickness and how it was derived. Describe methods to achieve sufficient compaction and homogeneous bonding between lifts. In case of larger area fills, describe how the old and new liner segments will be bonded together.

2. Geomembrane Liners.

a. Material Specifications. Describe the polymer type, fabric reinforcement, thickness and texture (e.g., smooth or textured for HDPE). Design specifications should indicate the type of raw polymer and manufactured sheet to be used as well as the requirements for delivery, storage, installation, and sampling of the geomembrane. Specific raw polymer and manufactured sheet specifications and test procedures include:

<u>Raw Polymer Specifications</u>

- Density (ASTM D-1505)
- Melt index (ASTM D-1238)

- Carbon black (ASTM D-1603)
- Thermogravimetric analysis (TGA) or differential scanning calorimetry (DSC)

Manufactured Sheet Specifications

- Thickness (ASTM D-5199)
- Tensile properties (ASTM D-638)
- Tear resistance (ASTM D-1004)
- Puncture resistance (ASTM D-4833)
- Carbon black content (ASTM D-1603/D-4218)
- Carbon black dispersion (ASTM D-5596)
- Dimensional stability (ASTM D-1204)
- Stress crack resistance (ASTM D-1693)

b. Chemical Compatibility. In case of industrial waste landfills, include a statement on the chemical compatibility of the liner and the leachate and cite the basis for the statement. If necessary, include the data from EPA Method 9090, SW-846.

c. Installation Specifications. Installation specifications should cover installation procedures specific to the properties of the liner installed.

- Ensuring that sufficient bedding will be provided above and below the liner to prevent rupture during installation and operation.
- Visual inspection and acceptance of the soil liner subgrade to be conducted prior to placing the geomembrane.
- The coefficient of thermal expansion of the geomembrane sheet as it affects its shrinking and expansion in the installation and its service performance.
- Information for protection of the material during shipping, storage and handling, quality control certifications required from the manufacturer or fabricator (if panels are constructed), and quality control testing by the contractor, installer, or a construction quality assurance (CQA) agent.
- A geomembrane layout plan, deployment of the geomembrane at the construction site, seam preparation, seaming methods, seaming temperature constraints, and seating of the geomembrane to appurtenances, both adjoining and penetrating the liner must be provided.

B. Leachate Collection and Removal System

1. Grading. The LCRS must be appropriately graded to assure that leachate will be drained to the system and equals or exceeds the minimum slope of two percent (the same slope as the cell liner) .

2. High Permeability Drainage Layer. Specify the materials that will be used to construct the layer. Note that the drainage material must have no more than 15 percent calcium carbonate equivalent.

(a) Soil Drainage Layer.

(1) Hydraulic Conductivity. Generally, gravel soil with a group designation of GW or GP on the Unified Soils Classification Chart can be expected to have a hydraulic conductivity of greater than 0.01 cm/sec, while sands identified as SW or SP can be expected to have a coefficient of permeability greater than 0.001 cm/sec. Specify the material for the soil drainage layer.

(2) Placement. Describe the equipment that will be used in layer placement and compaction, and the methods that will be used to check the thickness of the drainage layer.

(b) Geosynthetic Drainage Layers. The specifications for thickness and type of materials shall be identified on the drawings and shall be consistent with the design calculations. Describe method of placement and seaming, if any. Specify the design of the anchor trench and the placement of the geonet. Describe method of placement and seaming, if any.

3. Leachate Collection. The filter media, drainage layer, and pipe network specified should be compatible and represent an integrated design. All components of the leachate collection system must have sufficient strength to support the weight of the overlying waste, cover system, and post-closure loadings, as well as stresses from operating equipment. The specifications for thickness and type of materials shall be identified on the drawings and shall be consistent with the design calculations. Describe any methods of placement and seaming, if any. Specify the design of any anchor trench.

a. Hydraulic Conductivity. The hydraulic conductivity of the geotextile filter generally should be at least ten times the soil it is retaining. Assess the adequacy of flow by comparing the material (allowable) permittivity to the design imposed permittivity.[11] Specify the required factor of safety.

b. Retention. If a geotextile filter media is used, evaluate the retention ability for loose soils based on the average particle size of the soil and the apparent opening size (AOS) of the geotextile. Include the maximum apparent opening size (equivalent opening size) as determined by the size of the soil that will be retained. The material specifications should contain a range of AOS values for the geotextile, and these AOS values should match those used in the design. Include the results of the glass bead test and compare the retained distribution to the allowable values.[12]

4. Pipe Specifications. The collection system specifications shall include:

- Type of piping material to ensure that it is compatible with the leachate;[13]
- Manufacturer's quality control specification for the pipe material;
- Diameter and wall thickness sufficient to provide necessary flow and strength characteristics as indicated below;
- Method of joining the pipes;
- Description of pipe fittings;
- Size, location, and distribution of slots and perforations;
- Type of coatings (if any) used in the pipe manufacturing;
- Packaging shipping and storage of pipe;
- Conformance testing procedures and frequency;
- When pipe is imbedded in drainage materials, no unplugged ends can be allowed;
- Indicate the type of bedding to be used under the pipes and the dimensions of any trenches;
- For gravity-flow lines, a method for verifying the slope and alignment of the pipe after installation; and

[11] Use ASTM D-4491 to measure permittivity.

[12] U.S. EPA, "Seminar Publication - Requirements for Hazardous Waste Landfill Design, Construction and Closure," EPA/625/4-89/022; U.S. EPA; Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268 (1989).

[13] In case of industrial waste facilities, demonstrate that the LCRS components are chemically resistant to the waste managed in the landfill and the leachate expected to be generated.

- For pressurized lines (solid wall pipes), a means to test for leaks and quality installation.

5. Run-on and Run-off Control. Describe the methods to be employed to construct the run-on and the run-off control system. Based on the design calculations specify the type and size of the ditch or pipe used for run-on/off control. For ditches include the channel geometry and the liner material appropriate to the flow velocity for the design storm.

If sediment basins, or sediment ponds are used at the facility specify the volume of the basin, and specify the materials of construction.

V. QUALITY ASSURANCE AND QUALITY CONTROL. [§ 250.B.18., 260.B.17., or 270.B.19., 9 VAC 20-80-10] Reference: "Technical Guidance Document, Quality Assurance and Quality Control for Waste Containment Facilities, EPA/500/R-93/182."

C. General. A quality assurance/quality control program has two principal components. The first is the Construction Materials Quality Control, which is designed to ascertain that materials used meet specifications. The second component is the Construction Quality Assurance Program, which is designed to ascertain that the constructed facility meets the requirements described in the plans and specifications. The design report shall contain a quality assurance plan that addresses both components as they pertain to (as applicable):

- Foundations;
- Low-conductivity soil liners;
- Synthetic membrane liners; and
- Leachate collection and removal system.

The QA/QC plan shall specify the name and the affiliation of the construction quality control officer and shall describe in detail his responsibilities as they pertain to:

- Communicating with the contractor;
- Interpreting and clarifying project drawings and specifications with the designer, owner, and contractor;
- Recommending acceptance or rejection by the owner/operator of work completed by the construction contractor;
- Submitting blind samples (e.g., duplicates and blanks) for analysis by the contractor's testing staff or one or more independent laboratories, as applicable;
- Notifying owner or operator of construction quality problems not resolved on-site in a timely manner;

- Observing the testing equipment, personnel, and procedures used by the construction contractor to check for detrimentally significant changes over time;
- Reviewing the construction contractor's quality control recording, maintenance, summary and interpretations of test data for accuracy and appropriateness; and
- Reporting to the owner/operator on monitoring results.

Plans and Discussion. [§§ 520.A.1j and 520.B.3b, 9 VAC 20-80-10] Show a plan for initial site preparation and discuss the field measurements, photographs, and sampling and testing procedures to verify that the field conditions encountered were the same as those defined in the geotechnical report. Discuss the methods that will be used to document that the site was constructed according to the plans and specifications upon which the permit was based.

D. Foundations and Soil Liners. Quality control testing performed on materials used in construction of the foundations and soil liners includes source testing and construction testing. Describe the inspection, monitoring, sampling and testing methods and frequencies employed during foundation installation to assure that the foundation, as installed, meets the design requirements.

1. Construction Materials Quality Control. Source testing shall be performed to define material properties that govern material placement. Source testing shall include moisture content, soil density, Atterberg limits, grain size, and laboratory hydraulic conductivity. The plan shall specify methods and frequencies of sampling and analysis.

2. Construction Quality Assurance Program. Construction testing ensures that landfill construction has been performed in accordance with the plans and technical specifications. Construction testing generally includes soil moisture content, density tests, lift thickness tests, and hydraulic conductivity tests. The method of determining if the soil meets the required maximum hydraulic conductivity shall be specified in the QA/QC plan. The sample collection program shall be compatible with the testing to be performed. Selection of sample collection points should be made on a random basis. The CQA procedures to be used shall be selected from those generally accepted in the field.[14] If nuclear methods are

[14] U.S. EPA, "Design, Construction and Evaluation of Clay Liners for Waste Management Facilities," EPA/530/SW-86/007F; U.S. EPA; Office of Solid Waste and Emergency Response; Washington, DC 20460. NTIS PB-86-184496 (1988).

U.S. EPA, "Relationship of Laboratory- and Field-Determined Hydraulic Conductivity in Compacted Clay Layer," EPA/600/2-90/025; U.S. EPA; Risk Reduction Engineering Office; Cincinnati, Ohio 45268. NTIS PB-90-25775 (1990)

U.S. EPA, "Seminars - Design and Construction of RCRA/CERCLA Final Covers," CERI 90-50; U.S. EPA; Office of Research and Development; Washington, DC 20460 (1990) used for moisture and density measurements, alternate methods shall also be used to verify the accuracy of the faster nuclear methods. In-situ testing for hydraulic conductivity must be performed either on the test fill or the constructed soil liner.

3. Soil Liner Construction Test Pad. An owner or operator must construct a test pad to demonstrate the permeability of the liner soil. The test pad is used to verify that the soil, equipment, and construction procedures can produce a liner that performs according to the construction drawings and specifications. A test pad is required to determine how to build a soil liner, and functions as a construction quality assurance tool. If the procedures used to build a test pad that achieves a $1x10^{-7}$ cm/sec hydraulic conductivity are followed during liner construction, then the completed full size liner should meet the regulatory requirements.[15] Specific factors that can be examined and tested during construction of a test pad are:[16]

- Preparation and compaction of foundation material to the required bearing strength;
- Methods of controlling uniformity of the soil material (variability allowed in the borrow source);
- Compactive effort (e.g., number of passes) to achieve required soil density and hydraulic conductivity;
- Lift thickness and placement procedures to achieve uniformity of density throughout a lift and the absence of apparent boundary effects between lifts or between placements in the same lift;
- Procedures for protecting against desiccation cracking or other site- and season-specific failure mechanisms for the finished liner or intermediate lifts;
- Measuring the hydraulic conductivity on the test fill in the field and collecting samples of field-compacted soil for laboratory testing;
- Test procedures for controlling the quality of construction;
- Ability of different types of soil to meet hydraulic conductivity requirement in the field; and
- Skill and competence of the construction team including equipment operators and quality control specialists.

E. Geomembranes. Installation of geomembrane liners shall be in conformance with a

[15] U.S. EPA, "Seminar Publication - Requirements for Hazardous Waste Landfill Design, Construction and Closure," EPA/625/4-89/022; U.S. EPA; Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268 (1989).

[16] U.S. EPA, "Design, Construction and Evaluation of Clay Liners for Waste Management Facilities," EPA/530/SW-86/007F; U.S. EPA; Office of Solid Waste and Emergency Response; Washington, DC 20460. NTIS PB-86-184496 (1988).

quality assurance/quality control plan which includes the following:

- Observation of liner storage area and liners in storage, and handling of the liner as the panels are positioned in the cell;
- Observation of seam overlap, seam preparation prior to seaming, and material underlying the liner;
- Observation of destructive testing conducted on scrap test welds prior to seaming;
- Observation of destructive seam sampling, submission of the samples to an independent testing laboratory, and review of results for conformance to specifications;
- Observation of all seams and panels for defects due to manufacturing and/or handling and placement;
- Observation of all pipe penetration boots and welds in the liner;
- Preparation of reports indicating sampling conducted and sampling results, locations of destructive samples, locations of patches, locations of seams constructed, and any problems encountered; and
- Preparation of record drawings of the liner installation.

1. Geomembrane Materials Quality Control. The QA/QC plan shall prescribe the manufacturers quality control testing that shall be performed to determine if the properties of the synthetic materials delivered to the site meet the specifications required by the design.

Conformance samples shall be taken to confirm that the material received is consistent with what was required in the facility design and the construction specifications. The following tests should be performed on samples of geomembrane:

- Thickness (ASTM D-5199);
- Tensile strength and elongation (ASTM D-638 for polyethylene materials, ASTM D-882 for PVC, ASTM D-751 for CSPE-R);
- Puncture resistance (FTM std 101C for polyethylene materials only);
- Tear resistance(ASTM D-1004, Die C not for CSPE-R);
- Ply adhesion (ASTM D413, Machine method, type A for CSPE-R);

The quality control plan should specify the method of membrane sampling and the frequency of the conformance3 sampling. For rolled products the outermost 1 meter of material on the roll is usually cut for the entire width of the roll. Samples are usually taken on the basis of one sample for every 100,000 feet of geomembrane or one sample /lot - "lot" must be clearly defined in the plan.

2. Construction Quality Assurance.

a. Inspection Activities. Inspection activities, including both nondestructive and destructive quality control field testing of the sheets and seams during installation of the geomembrane. Describe how the following will be taken into account:

- Ambient temperature at which the seams are made;
- Relative humidity;
- Control of panel lift up by wind;
- Water content of the subsurface beneath the geomembrane;
- Supporting surface on which the seaming is bonded;
- Skill of the seaming crew;
- Quality and consistency of the chemical or welding material;
- Proper preparation of the liner surfaces to be joined; and
- Cleanliness of the seam interface (e.g., the amount of airborne dust and debris present).

In the case of composite liner construction, provide the description how intimate contact between the synthetic and the soil liners will be determined.

In addition to the inspection requirements shown in above the QA/QC plan shall provide for testing of the integrity of geomembrane seams. The following test methods shall be used:

b. Destructive Testing. Destructive peel and shear field tests are to be performed on samples from installed seams. The samples may be collected randomly or in areas of suspect quality. Sampling protocols should follow those shown in U.S. EPA, "Technical Guidance Document: The Fabrication of Polyethylene FML Field Seams," EPA/530/SW-89/069; U.S. EPA; Office of Solid Waste and Emergency Response; Washington, DC 20460. NTIS PB-90-119595 (1989). Normal sampling frequency is one destructive sample per 500 feet of seam. Destructive samples of installed seam welds shall be cut into several pieces and distributed for the following purposes to:

- The installer to perform construction quality control field testing;
- The owner/operator to retain and appropriately catalog or archive; and
- An independent laboratory peel and shear testing.

c. Non-destructive Testing. Non-destructive test methods are to be conducted in the field on an in-place geomembrane. These test methods determine the integrity of the geomembrane field seams. Nondestructive test methods include the probe test, air lance, vacuum box, ultrasonic pulse echo, ultrasonic impedance plane, electrical spark test, pressurized dual seam, electrical resistivity, and hydrostatic tests. Detailed discussion of these test methods may be found in USEPA guidance document cited above.

F. LCS Quality Assurance. The design report shall include a description of the QA/QC plan for the leachate collection and removal system. The purpose of leachate collection system CQA is to document that the system construction is in accordance with the design specifications.

1. Materials Quality Control. The plan shall require that prior to construction, all materials should be inspected to confirm that they meet the construction plans and specifications. These include:

- Geonets;
- Geotextiles;
- Pipe size, materials, and perforations;
- Granular material gradation and prefabricated structures (sumps, manholes, etc.);
- Mechanical, electrical, and monitoring equipment; and
- Concrete forms and reinforcement.

2. CQA Program. The plan shall describe how the leachate collection system foundation (geomembrane or low permeability soil liner) shall be inspected and surveyed upon its completion to ensure that it has proper grading and is free of debris and liquids. During construction, the following activities, as appropriate, shall be observed and documented:

- Pipe bedding placement including quality, thickness, and areal coverage;
- Granular filter layer placement including material quality and thickness;
- Pipe installation including location, configuration, grades, joints, filter layer placement, and final flushing;
- Granular drainage layer placement including protection of underlying liners, thickness, overlap with filter fabrics and geonets if applicable, and weather conditions;
- Geonet placement including layout, overlap, and protection from clogging by granular material carried by wind or runoff during construction;
- Geotextile/geofabric placement including coverage and overlap;

- Sumps and structure installation; and
- Mechanical and electrical equipment installation including testing.

In addition to field observations, actual field and laboratory testing shall be performed to document that the materials meet the design specifications. These activities shall include the following:

- Geonet and geotextile sampling and testing;
- Granular drainage and filter layer sampling and testing for grain size distribution; and
- Testing of pipes for leaks, obstructions, and alignments.

Upon completion of construction, each component shall be inspected to identify any damage that may have occurred during its installation, or during construction of another component (e.g., pipe crushing during placement of granular drainage layer). Any damage that does occur shall be repaired, and these corrective measures shall be documented in the CQA records.