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Presumptive Remedies: CERCLA Landfill Caps RI/FS Data Collection Guide

Office of Emergency and Remedial Response
Hazardous Site Control Division (5203G)

Quick Reference Fact Sheet

Municipal landfills constitute approximately 20 percent of all sites on the Superfund National Priorities List. Approximately 75 percent of all CERCLA Municipal Solid Waste Landfill (MSWLF) Remedial Actions call for installation of a landfill cap. The remedy selection process for MSWLFs is the basis of a U.S. Environmental Protection Agency (EPA) guidance, *Conducting Remedial Investigation/Feasibility Studies for CERCLA Municipal Landfill Sites* (U.S. EPA, 1991), which establishes the framework for containment (including landfill cap construction, leachate collection and treatment, ground water treatment, and landfill gas collection and treatment) as the presumptive remedy for MSWLFs.

In 1992, EPA introduced the *Superfund Accelerated Cleanup Model (SACM)* to accelerate all phases of the remedial process. The presumptive remedy initiative is one tool for speeding up cleanups within SACM. One way that presumptive remedies can streamline the remedial process is through early identification of data collection needs for the remedial design. By collecting design data prior to issuance of the Record of Decision (ROD), the need for additional field investigations during the remedial design (RD) will be reduced, thereby accelerating the overall remedial process for these sites. Data needed for design also can be useful in better defining the scope of the remedy and in improving the accuracy of the cost estimate in the ROD. Since containment is the presumptive remedy for MSWLFs, the Remedial Project Manager (RPM) can begin making arrangements to collect landfill cap design data as soon as a basis for remedial action is established (e.g., ground water contaminant concentrations exceeding maximum contaminant levels [MCLs]).

This fact sheet identifies the data pertinent to landfill cap design that will be required for most sites. These data are organized within six categories: (1) waste area delineation; (2) slope stability and settlement; (3) gas generation/migration; (4) existing cover assessment; (5) surface water run-on/run-off management; and (6) clay sources. For reference, all data requirements and data collection methods discussed in this document are summarized in a table at the end of this document (Table 2). In addition to the following guidance provided in this fact sheet, RPMs should enlist the aid of technical experts familiar with landfill cap design in establishing data collection needs for specific sites.

TECHNICAL AREA 1: WASTE AREA DELINEATION

The area of a landfill cap is determined by the horizontal extent of previous waste disposal. One of the major causes of cost escalation for MSWLF sites has been the failure to establish the actual boundaries of the waste. Costly construction change orders have been required to increase the area of the cap because wastes have been found to extend well beyond the edges of the intended cap. Waste boundaries should be identified as accurately as practicable prior to initiation of the design.

Aerial photographs, maps, and a local newspaper subject search may provide a historical record of the extent and type of disposal activities conducted at the site. If appropriate, residents could be interviewed to confirm or supplement available information.

Field investigation should be used to confirm records and to collect data to delineate the outer boundaries of the waste. Field investigations normally include surface, subsurface, and noninvasive geophysical explorations. Field investigation methods that provide information on the surface and shallow subsurface extent of waste include excavating shallow test pits, using direct-push exploration techniques, and drilling boreholes. Additional subsurface investigation methods are used to provide information on the vertical extent of waste.

Borings can be used to estimate waste thickness and condition of existing cover soils adjacent to or underlying the waste.

However, drilling into or through the waste and into the underlying soils and/or bedrock should be performed only if necessary, and only if the driller is experienced in the methods used to prevent cross-contamination. Additional health and safety concerns (especially exposure to methane gas) must be addressed in the health and safety plan when borings are located in the waste.

Visual evidence of the waste boundary or subsurface contamination from these field investigation activities should be recorded and, if necessary, verification samples should be collected and shipped for laboratory analyses.

Surface geophysical methods also may be useful in delineating the waste boundary. Each method has limitations, and the selection of an appropriate method should be based on landfill characteristics and data needs. The most commonly employed geophysical methods include:

- Magnetometry (measures minor changes in earth's magnetic field)--location of waste boundary and distribution of metallic waste

- Electromagnetic Conductivity (response to artificially induced magnetic field)--location of areas of contrasting conductivity, such as a landfill or natural deposits

- Ground-Penetrating Radar (reflection of electromagnetic waves)--determination of horizontal extent and depth of disturbed soils and buried objects (often used to confirm magnetometry)

- Electrical Resistivity (measures earth's response to electrical current)--determination of edge of landfill by subsurface resistivity difference

- Seismic Refraction (natural or induced compression waves)--estimation of depth to geologic strata and bedrock adjacent to the landfill.

These noninvasive surface geophysical methods should be performed prior to invasive explorations (e.g., borings or test pits). This will allow for the more limited intrusion activities to verify the findings of the noninvasive exploration methods.

TECHNICAL AREA 2: SLOPE STABILITY AND SETTLEMENT

Waste settlement and/or slope failure of the waste and existing cover soils can occur during construction of, or after completion of, the cap. Waste settlement or slope failure (see Figure 1) may expose waste and require costly repairs. Data are needed on degree of slope, existing cover materials, and existing cover soils to create cross-sectional diagrams for use in evaluating landfill slope stability and the potential for settlement damage.

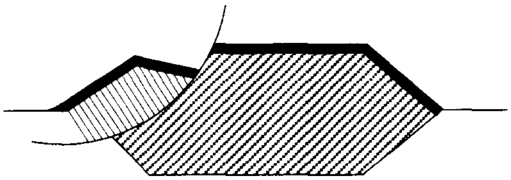

Figure 1. Typical slope failure at MSWLF site.

Settlement in a landfill can be caused by factors such as: biodegradation of wastes, consolidation of waste under the weight of waste material and cap, deterioration of partially filled containers (e.g., drums), or compaction of material during landfill operation or cap installations. Possible consequences of settlement include instability in the waste or cover soil, which can damage the cap. In fact, a recent article on cap design reports that "The center of a 20-foot diameter section of a landfill cover, for instance, could settle only 0.5 to 1.5 feet before significant cracking [of the composite clay liner] could be expected." (Koerner and Daniel, 1992) For this reason, settlement potential and stability of the landfill system should be evaluated concurrently.

The weight of the new cap can be significant enough to cause additional waste settlement and compaction. The effect of this additional weight may initiate differential settlement across the cap, thus compromising the integrity of the cap, or create stability problems such as slippage failures in the waste and/or existing cover soil. Differential settlement occurs when one area of waste settles more readily than another because of differences in moisture content, waste compaction, or waste composition. Settlement (magnitudes typically range from 5 to 25 percent of the initial waste thickness), and especially differential settlement, may create cracks in the cap and allow rainwater to reach the waste. Changes in the topography of the landfill because of settlement may also create areas on the cap surface where rainwater can pond.

In creating the conceptual landfill cap design, three separate calculations are conducted

- Stability of waste--largely depends on how well the waste was compacted when placed, waste layer thicknesses, and waste composition

- Stability of the cap (existing and proposed)

- Settlement of waste—largely depends on how well the waste was compacted when placed, waste layer thicknesses, age, rate of waste degradation, and waste composition.

Because of their heterogeneous nature, the settlement and stability of municipal wastes are difficult to predict. Settlement rates of selected areas of the waste can be measured by placing survey monuments on top of the waste and taking periodic measurements to determine the change in elevation of the monuments. Because settlement generally occurs slowly, it is important to begin measurement early, preferably during the remedial investigation.

The settlement of the waste depends on thickness and general composition of the waste and existing topography. Compressibility characteristics are derived from preload tests and empirical correlations to data in the published literature. Data from surveying monuments, settlement plates, and topographic surveys can be used to determine surface settlement rates across the landfill.

The stability of waste can be determined by evaluating the following:

- Potentiometric surface and perched water table information--can be determined using water level measurements from piezometers and monitoring wells
- Thickness of waste
- Existing topography-can be determined from site reconnaissance and topographic surveys.

Ground motions induced by earthquakes (seismic events) can also affect cap performance through a decrease in slope stability. This fact sheet does not address the additional data required for cap designs for landfills located in seismic impact zones.

The waste thickness and composition can be determined by observing and sampling (during completion of test pits, borings, and hand-augered holes with an experienced driller) and by searching through historical records.

The existing cover soil should also be evaluated to determine its stability and potential for settlement. Studies for the stability of the existing cover soil could include:

- Maximum Slope
- Soil classification
- Potentiometric surface
- Shear strength
- Thickness
- Density

Slope measurements and potentiometric surface derivations can be obtained using the same procedures used to determine waste characteristics. The remaining data can be obtained by boring, piezocone penetrometer (PCPT), geophysical techniques, and test pits. Existing cover soils should be classified by grain size and hydrometer analysis, as well as by Atterberg limits performed on borings and test pit samples. See the summary table at the end of this fact sheet (Table 2) for recommended tests to determine the shear strength for fine- and coarse-grained soils.

The stability and settlement estimates for existing cover soil depend largely on the complexity of the landfill site. Investigations necessary to evaluate physical properties of the existing cover soils will depend on the type(s) of soils encountered. If the existing cover soils are soft silts and clays, the settlement and stability evaluations will be more complex than for sands and gravels. These soil samples should be collected during drilling of monitoring wells to save time and money, usually during the remedial investigation (RI).

Additional slope stability evaluations will be performed during landfill cap design. Slopes greater than 3:1 (3 horizontal/ 1 vertical) and landfills that have been constructed within or adjacent to wetlands or low-strength soils are of particular concern. These areas of concern should be identified during RI/FS data collection to the extent possible.

TECHNICAL AREA 3: GAS GENERATION/MIGRATION

Assessment of the rate and composition of gas generated in the landfill will determine whether or not a gas collection layer should be included as a component of the cap. Dangers of gas generation and uncontrolled migration include vegetative kill, health risks from exposure, and explosive or lethal gas buildup within and outside of the landfill (see Figure 2). Field monitoring for the presence of landfill gases is also important in developing safety parameters and reducing health risks to personnel working on site.

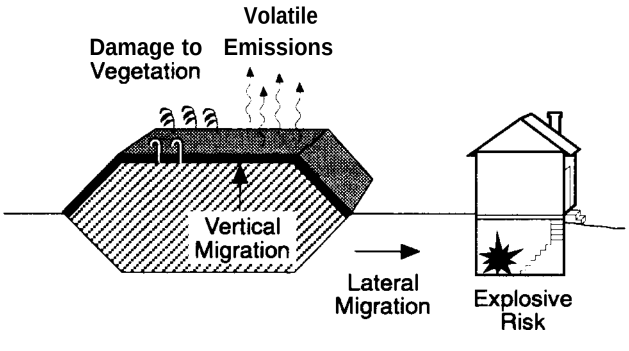

Figure 2. Vertical and lateral migration of generated gas from MSWLF site.

Generation of gas typically results from the biological decomposition of organic material in the wastes. The rate and process of gas generation are dependent on the availability of moisture, temperature, organic content of the waste, waste particle size, and waste compaction.

Data immediately available in the field for assessing gas generation are landfill gas composition and gas pressure. Gas composition in soils usually is evaluated in the field by monitoring or sampling through gas probes using a methane meter, explosimeter, or organic vapor analyzer. Air samples should be analyzed for the presence of volatile organic compounds (VOCs) or semivolatile organic compounds

(SVOCs). Moisture and heat content also can be determined by the laboratory or in the field with hand-held instruments. This information may be necessary to assess possible treatment alternatives for collected gas.

Gas migration is a function of site geology, chemical concentration, and pressure and density gradients. Gases migrate through the path of least resistance (e.g., coarse and porous soils, bedding stone along nearby water and sewer lines). Data for evaluating gas migration control and treatment methods include the composition of any existing landfill liners, soil stratigraphy, depth to water table, proximity of human/ecological receptors, and the locations of buried utilities and other backfilled excavations and structures.

Gas migration pathways may be identified based on knowledge of the site geology, hydrogeology, and surrounding soil characteristics and by review of water and sewer maps. Some of these data may be obtained by collecting and evaluating samples from test pits, borings, or hand-augered holes. Piezocone data also may be cost-effective for characterizing the surrounding subsurface soils at larger MSWLF sites.

Potential receptors of landfill gas emissions may be identified through site reconnaissance, and receptor locations should be monitored to assess possible accumulation of migrant landfill gases. Atmospheric monitoring at receptor locations may be done using a flame ionization detector (FID), a photoionization detector (PID), or a gas monitoring station; however, a PID will not detect methane and thus cannot be used to assess explosion risk. An oxygen meter using the Lower Explosive Limit (LEL) indicator may be used to detect explosive levels of gas.

Gas control is accomplished through either passive or active gas collection. Treatment of collected gas may be required depending on the concentration of hazardous constituents. The gas control system required will depend on the proximity of receptors, permeability of migration pathways, State and Federal regulations and guidelines, and level and rate of gas generation. Effective gas disposal methods include flaring, processing and sale, and/or sorption.

Active gas collection may be necessary to control gas migration when receptors are, or are expected to be, at risk. Active gas collection generally is required when measurements exceed either

- 5% methane at the property line or cap edge, or
- 25% methane LEL in/at on-site structures. (This subject is further addressed in the U.S. EPA Technology Brief *Data Requirements for Selecting Remedial Action Technology* [U.S. EPA, 1987].)

A gas pumping test can be used to improve the estimate of the gas permeability of the waste materials and unsaturated soils, number of collection wells required, piping size and configuration, and blower requirements. However, gas pumping tests should not be relied on without further measurement and adjustment during construction.

TECHNICAL AREA 4: EXISTING COVER ASSESSMENT

Existing landfill caps should be evaluated to determine whether or not any components can be reused in the construction of a new cap. Use of existing components could save both time and money.

Data on existing components can be readily collected because only materials above the waste need be sampled. Sampling locations and procedures that will minimize damage to geosynthetic materials should be used. Sampling holes should, at a minimum, be refilled with bentonite if the existing cap is composed of clay. Geosynthetics should be patched with materials of equal properties following manufacturer's guidelines.

Additionally, the site reconnaissance should be used to evaluate, in general, the need for regrading the landfill surface to achieve proper side slopes. Appropriate limits to the steepness of slopes can be determined from preliminary slope stability calculations. Excavation into landfill waste materials may be required to reduce slope steepness to acceptable limits.

Table 1 provides recommended guidelines for final cover designs. The assessment of the existing cover should include an evaluation of the potential for any components to meet final cover guidelines.

Table 1. Existing Cover Assessment Data Requirements and Recommended Guidelines

Data Requirements	Recommended Guidelines[A] (for Final Cover)
Slope (top)	3% to 5% minimum for drainage
Cap Area	Covers horizontal waste limits
Vegetative/Soil Layer	Vegetative soil supporting healthy low shrubs or grass, no erosion, gullies or deep-rooted plants, no unacceptable frost heaves or settlement
Drainage Layer	Permeability $>1 \times 10^{-2}$ cm/s (sand, gravel, or geosynthetic)
Barrier Layer	Two-component (geomembrane atop compacted clay[b]) composite liner below the frost zone
Gas Venting System	Either passive vents located at high points (not clogged, no settlement) or extraction and treatment system working properly

[a] Refer to EPA's Technical Guidance Document: *Final Covers on Hazardous Waste Landfills and Surface Impoundments* (U.S. EPA, 1989).

[b] Clay compacted to a permeability $\leq 1 \times 10^{-7}$ cm/s, geomembrane thickness $\geq$ 20 mil.

TECHNICAL AREA 5: SURFACE WATER RUN-ON/RUN-OFF MANAGEMENT

The surface area and gradient of landfill slopes will affect surface water control measures. For the protection of both the landfill cap and adjacent areas (see Figure 3), the design of the final remedy should ensure that the site layout will provide adequate space for surface water diversion and containment/retention impoundments.

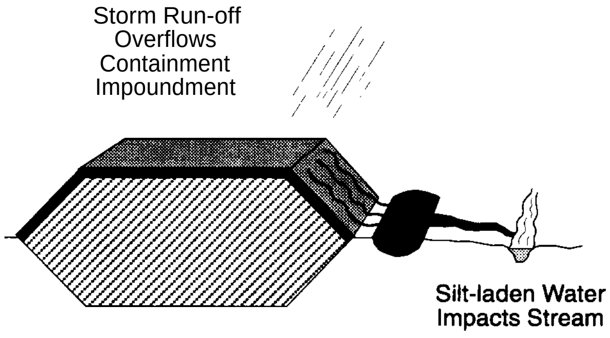

Figure 3. Storm run-off impact from an MSWLF site.

RCRA Subtitle D minimum requirements for MSWLFs (40 CFR Section 258.26) include providing a run-on control system capable of preventing flow onto the active portion of a landfill during the peak discharge from a 25-year rain storm. The regulation also requires providing run-off control systems to collect, at a minimum, the water volume resulting from a 24-hour, 25-year rainstorm. RCRA Subtitle D regulations apply to the closure of active MSWLFs and may be Applicable or Relevant and Appropriate Requirements (ARARs) for certain landfills at CERCLA sites as well.

The method for estimating run-on and run-off design discharges should be based on engineering judgment and on-site conditions (e.g., the Rational Method used by hydrologists to determine overland flow). Detailed storm flow calculations usually are done during the design phase. However, data for preliminary calculations should be collected early enough to prepare an estimate of the cost of run-on/run-off control measures as part of the remedy estimate for the ROD.

Because run-on and run-off control is required for operating landfills, some landfills may already have surface water diversion or containment impoundments that allow sediment to settle out of the run-off and that control discharge for a 25-year storm. Depending on when the landfill was designed (with respect to applicable Federal and State regulations), existing control structures may not have adequate capacity. In addition, the RI/FS should identify areas for temporary surface water controls for use during cap construction activities.

A review of the original design or site records available for a landfill may provide information on design criteria for the surface water control structures. Site reconnaissance should be conducted to evaluate the physical condition of the system. If there are no existing diversion or containment impoundments, adequate space should be located on or off site to accommodate them. Property acquisition may be necessary if on-site space is not available.

Prior to cap installation, collected or diverted run-on surface waters often can be discharged to a nearby surface waterbody or to a recharge basin. Discharge to surface water is considered a point source discharge and must comply with the National Pollution Discharge Elimination System (NPDES) requirements of the Clean Water Act. Because many States have jurisdiction for the discharge of pollutants to surface waters, permit requirements may vary depending on location, although an NPDES permit is always needed. Other factors to consider are the water quality and soil type, which can be determined by analysis of surface water samples, visual and sieve analyses of the soil, and review of NPDES compliance data (if applicable).

After the cover is installed, the collected or diverted surface water is not contaminated; therefore, diversion or containment impoundment maintenance usually is limited to control of vegetation and debris and sediment removal. Discharge to a recharge basin is not considered a point source discharge and, generally, regulators evaluate these basins for permit compliance on a case-by-case basis.

TECHNICAL AREA 6: CLAY SOURCES

A compacted clay layer is normally one of the primary components of an effective cap, provided that sources of clay (low-permeability soil) are available at or near the landfill. Data-gathering activities should include looking for potential on-site/local clay deposits for the cap construction. Manufactured geosynthetic clay liners should be considered if the required volume or physical properties are not available in nearby soils. A comparison of geosynthetic clay liner material cost versus clay excavation and transport cost should be completed before design commences.

Investigation of potential sources for clay should be initiated prior to the preliminary conceptual cap design (which defines the components of the cover). For information on clay deposits, the Soil Conservation Service (SCS) of the U.S. Department of Agriculture (USDA) publishes soil maps and classifications by county. Additional information on the availability of clay soils may be obtained from State natural resource inventory programs; local contractors or engineering firms practicing in the area; State and local highway officials, shallow borings, test pits, and hand-augered holes; and geotechnical laboratory testing.

After potential sources of clay are identified, a site reconnaissance may be conducted. The site reconnaissance should include sample collection via hand-augered holes or shovels to verify the availability of clay over the site.

Subsurface soil samples of the source area should be collected later to determine resource quality (shear testing of layer interfaces) and quantity. Procedures used to characterize clay sources generally include:

- Excavation of at least one test pit for every 25,000 to 50,000 cubic yards
- Collection of soil samples from test pits for laboratory characterization
- Shallow borings to confirm soil type, volume, and, in certain instances, depth to ground water
- Laboratory testing of samples collected including: grain size analysis, Atterberg limits, permeability testing, moisture content, and compaction testing. Detailed compaction requirements to meet construction quality assurance objectives are provided in *Quality Assurance and Quality Control for Waste Containment Facilities* (U.S. EPA, 1993 b).

If sufficient quantities of soil cover materials with appropriate engineering properties are not available within an economically practicable distance from the project site, geosynthetics or processed natural materials should be considered. Geosynthetic clay liners are generally manufactured by either sandwiching bentonitic clays between geotextiles or affixing the bentonitic clay to the bottom surface of a membrane. Thus, if clay is not readily available, low-permeability layers of the cap may be comprised of either available soil that is processed by adding bentonite to reduce the permeability or geosynthetic clay liners. For cap drainage layers, geosynthetic drainage nets may also be used, in lieu of coarse sand and gravel, to meet performance requirements. Information on geosynthetic clay liners and drainage nets can be obtained from manufacturer catalogues.

CONCLUSION

For each MSWLF site where capping is clearly a preferred remedy, the RPM should assemble a technical review team to determine the design data to be collected. This team should include experienced RPMs and technical experts familiar with data collection needs for cap design. The team can help the RPM in defining the field work required and its timing and in reviewing the design data submitted by the contractor. In the event that the contractor is changed (i.e., the RI/FS is Fund-led and the design is switched to Potentially Responsible Party [PRP]-led), the technical review team can assist the RPM in transferring the pertinent collected design data to the new contractor.

Table 2 summarizes the data needs and collection methods presented in this fact sheet. This table should be used as a reference when determining necessary design data collection activities.

Table 2. Data Requirements and Collection Methods

Data Requirements	Data Collection Methods
Waste Area Delineation	
Design/historical information	Historical records, personal interviews
Horizontal extent of waste	Test pits, probes, hand-augered holes, magnetometry, electromagnetic conductivity, ground-penetrating radar, electrical resistivity, seismic refraction
Depth and thickness of waste	Borings, geophysical surveys
Slope Stability and Settlement[a]	
Waste Evaluation	
Slope measurement (A)	Slope inclinometers, topographic survey
Potentiometric surface (A)	Piezometers/monitoring wells
Compressibility characteristics (C)	Preload testing, empirical correlations to published literature
Settlement rate (C)	Survey monuments, settlement plates, topographic survey
Thickness of waste (A,C)	Observation and sampling during test pits, borings, hand-augered holes, historical records, geophysical surveys
General waste composition (A,C)	Observation and sampling during test pits, borings, hand-augered holes, historical records, geophysical surveys
Existing topography (A,C)	Site reconnaissance, topographic survey, historical photographs

(continued)

Table 2 (continued)

Data Requirements	Data Collation Methods
Existing Cover Soil Evaluation[a]	
Slope measurement (A,B)	Topographic survey, slope inclinometers
Soil classification (B)	Grain size analysis, hydrometer analysis, Atterberg limits performed on borings/test pit samples
Potentiometric surface (A,C)	Piezometers/monitoring wells
Shear strength (B)	Fine-grained soil (cohesion): Field and/or lab vane shear test, torvane, pocket penetrometer, piezocone penetrometer, unconfined compressive strength, empirical correlations to Standard Penetration Test (S-P-T) Coarse grained soil (friction angle): Empirical correlations to S-P-T, direct shear test, triaxial shear test, piezocone penetrometer
Compressibility characteristics (C)	Consolidation tests performed on undisturbed tube samples collected from borings. Empirical correlations to index properties (water content, plasticity).
Density (B)	Empirical correlations to S-P-T data, bulk density determination from undisturbed tube samples (fine-grained soils only)
Gas Generation/Migration	
Gas composition and gas pressure	Gas probes, monitoring wells, laboratory samples
Moisture and heat content	Laboratory samples or handheld instruments in the field
Migration pathways	Water and sewer maps, piezocone, test pits, borings, hand-augered holes
Receptors	Site reconnaissance, photoionization detector, flame ionization detector, air monitoring station, oxygen meter
Existing Cover Assessment	
Slope-top	Site reconnaissance, topographic survey
Cap area	Site reconnaissance, borings, test pits, geophysical survey
Vegetative/soil layer	Site reconnaissance, topographic survey, test pits
Drainage layer	Site reconnaissance, borings, test pits, hand-augered holes, field infiltrometer or laboratory samples for hydraulic conductivity
Barrier layer	Test pits, borings, hand-augered holes, Shelby tubes for permeability, laboratory samples/analysis for shear strength, compaction curve, atterberg limits, freeze/thaw cycling, water content
Gas venting system	Site reconnaissance, gas character sampling, gas pumping tests
Run-on/Run-off Management	
Estimated discharge, size of control structures, treatment requirements	Review of design records, National Pollutant Discharge Elimination System (NPDES) permit, detailed storm flow calculations
Climatic data	National Oceanographic and Atmospheric Administration (NOAA)
Run-on/run-off areas (% vegetated, % paved)	Site reconnaissance, topographic surveys, aerial photographs
Water quality	Surface water sampling and analysis
Soil types	Visual, aerial photographs, and soil maps from the Soil Conservation Service (SCS)
Clay Sources	
Soil properties	Soil maps from the SCS, local contractors or engineering firms, state/local transportation officials, natural resource inventory programs, shallow borings, hand-augered holes, test pits, and geotechnical laboratory testing
Subsurface resource adequacy and quantity (shear testing)	Grain size analysis, Atterberg limits, permeability test, moisture content, compaction test, shallow borings, test pits, laboratory testing
Geosynthetic clay liner properties	Manufacturer catalogs, literature, EPA studies/guidance

[a] The letters following the slope stability and settlement and existing cover soil evaluation data requirements are referenced to the data needed to perform the three separate calculations used to evaluate slope stability and settlement of the landfill cover (see Technical Area 2):

A = Stability of waste. B = Stability of cap components. C = Settlement of waste.

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