**WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY**
**SOLID AND HAZARDOUS WASTE DIVISION**

# SOLID WASTE GUIDELINE #23

# "Site Characterization for Landfill Siting and Design"

## 1.0 Introduction

The purpose of this document is to provide guidance for collecting and submitting to the Wyoming Department of Environmental Quality, Solid and Hazardous Waste Division (Department) the information that is necessary to determine the suitability of a proposed disposal site or expansion area, and to design the disposal area such that protection of human health and the environment are assured. Site characterization information will be used in the facility design, and may affect subjects such as depths of disposal, engineered containment systems (ECS), groundwater monitoring requirements, or other design or operating factors. This information is submitted as part of an application for obtaining, renewing, or modifying an operating permit for a sanitary or industrial landfill.

It is important to note that this guideline describes work needed for site characterization, and that after site characterization is complete it may be necessary to install additional wells to complete the routine groundwater monitoring network. While portions of this guideline are applicable to other facilities or uses, the primary focus of this guidance is characterization of new sites or lateral expansions of existing sites for use as municipal or industrial landfills. This guidance is focused primarily on the process and data needs for parties interested in demonstrating that an ECS is not needed for a proposed landfill. The level of information needed for investigation of a lined landfill will be somewhat less than that for a proposed unlined facility, especially in terms of data needed for fate and transport modeling. However, the investigative methods that should be used are similar for both unlined and lined facilities. Also, the use of statistical methods for analysis of groundwater data has long been recognized, and is an integral part of the groundwater monitoring section of the Wyoming Solid Waste Rules and Regulations (SWRR). For this reason information is included regarding the minimum number of groundwater samples that will be needed for statistical analysis. Depending on site specific conditions and the statistical method selected more than the minimum number of samples may be needed.

The information in this document should not be interpreted by applicants or Department staff as mandatory. Proposals for alternate approaches will be considered by the Department on a case-by-case basis.

## 2.0 Background

Historically the Department has not provided specific written guidance regarding the information needed for site characterization. The purpose of past site characterization efforts was mainly to identify subsurface water-bearing zones, to avoid designing landfills where wastes would be placed in contact with groundwater. Information about soil types was also collected, to allow a qualitative evaluation of the facility's likely impacts on groundwater quality. Historically, landfills in the arid west were not expected to generate enough leachate or landfill gas to impact groundwater. Data now shows that this assumption was wrong. Consequently, a growing number of unlined landfills in Wyoming are reporting groundwater pollution. This and other information has led the Department to conclude that a more rigorous, site-specific technical approach must be used to evaluate alternative ECS designs. Guidelines have been prepared to outline an approach that consists of:

- Evaluating site specific geologic and hydrogeologic information;
- Evaluating leachate generation rates using the HELP model and local climate data; and
- Using contaminant fate and transport modeling to evaluate migration of contaminants to groundwater.

In the past, long term planning and site characterization for future development areas of a facility have been lacking at many facilities in Wyoming. This has resulted in problems for some facilities, where unanticipated site conditions were found which resulted in a significant reduction of expected facility life. One Wyoming facility's life was reduced from 40 years or more to less than ten years, because of the discovery of shallow groundwater in a portion of the facility. To avoid these types of problems, permit applications need to include site characterization plans for phased site development. Planning for a single permit term is not adequate. Plans need to include the collection of detailed information to adequately characterize areas large enough to provide at least 20 years of disposal capacity. Then after 10 years of operation, work needs to begin to develop detailed information for the area to be used for the next 20 to 30 years. This will result in a facility having plans developed for a period of 18 to 20 years into the future. The Department believes that this approach balances the need for long-term planning with the possibility that new site information or changes in disposal practices could necessitate changes in facility design.

The same concept of developing detailed plans for disposal in approximate 20 year blocks also applies to proposals for alternative designs that do not include ECS. Alternative design proposals will be approved for specific areas of a facility where adequate data have been collected to support such designs, unless the entire site is characterized in adequate detail during the initial permitting process. If the entire site is not initially characterized to the degree necessary for evaluating the appropriateness of an alternative design and the applicant wants to pursue an alternate design for areas of a facility being considered for future use, adequate data which focuses on these areas will need to be collected prior to design and operation of the proposed waste disposal units.

The Department is frequently asked how deep borings or wells need to be drilled. In order to provide a reasonable, consistent answer to this question, the Department has considered several different factors. First, existing information was reviewed regarding known depths to groundwater at existing solid waste disposal facilities in the state. Approximately eighty percent of currently operating municipal solid waste (MSW) landfills have encountered groundwater within one hundred feet of the surface. It should be noted that nine facilities have not drilled to a depth of one hundred feet; thus the percentage that may have groundwater within one hundred feet of the surface may be more than eighty percent. Second, groundwater impacts resulting from migration of leachate to groundwater are confirmed or suspected at numerous MSW landfills in Wyoming. Thus, the previously held assumption that groundwater impacts will not occur due to leachate migration from unlined landfills in arid environments was wrong. Third, groundwater impacts from MSW landfills in Wyoming have been demonstrated at depths in excess of 150 feet below ground surface. Fourth, a survey of currently operating lined landfills in semiarid and arid areas surrounding Wyoming showed that every facility contacted is generating leachate. Fifth and last, when subsurface information is used to propose an alternative ECS design or groundwater monitoring system, the Department must have confidence that the data used to support these proposals represents a thorough and comprehensive evaluation of site conditions. Based on the above five factors, the Department believes it is appropriate and necessary to drill at least two hundred feet below the proposed base elevation of waste, or at least ten feet into groundwater, whichever is shallower. In some cases, such as when permeable materials are present, it may be necessary to drill to greater depths.

## 3.0 Regulatory Considerations

Chapter 2 of the SWRR contains several regulatory standards related to site characterization. These standards include:

- Chapter 2, Sections 2(b)(iii)(A)(VII) related to available regional geologic or hydrologic information
- Chapter 2, Sections 2(b)(iii)(A)(VIII ) related to information known to applicants that would limit a site's suitability as a sanitary landfill
- Chapter 2, Sections 2(b)(iii)(A)(IX )(1) through (7) related to site specific data on geologic and hydrogeologic conditions
- Chapter 2, Section 6 (b) (i) (B) describes the minimum requirements for a groundwater monitoring system
- Chapter 2, Section 7 (d) describes requirements for final cover permeability

The conditions under which an ECS is required at new Type I landfills, new cells at existing Type I landfills, and horizontal expansions of area cells at existing Type I landfills are described in Chapter 2 Section 4 (j)(i) of the SWRR. An ECS is required unless the operator demonstrates to the administrator that all of the following conditions are met:

X Native soils underlying the landfill are sufficiently impermeable to prevent potential contamination of groundwater through operation of the facility; and

X Waste types or operating practices minimize the potential for contamination of underlying soils and/or groundwater; and

X Site hydrologic conditions are sufficient to protect groundwater from contamination; and

X The facility receives less than 500 short tons of unprocessed household refuse or mixed household and industrial refuse per operating day, on a monthly average.

For Type II landfills, as described in Chapter 2 Section in 4 (j) (iii) of the SWRR, the administrator may determine, after evaluating the same conditions used for Type I landfills, that an ECS is required to protect public health and the environment. To allow consideration of alternative approaches, site-specific conditions and changing technologies, the SWRR above do not contain prescriptive information regarding how an operator must demonstrate that the above conditions are met. The Department has developed this and other guidance to address these technical issues.

## 4.0 Work Plan Content

There are several different approaches that may be taken to characterizing sites for new solid waste disposal facilities. If an applicant is performing preliminary work at multiple sites to gain basic knowledge of soil types present, it may be appropriate to drill just a few borings for lithologic information at each site. The work plan contents described below are intended to address a focused investigation at a site that is being investigated in detail.

It may be desirable in some cases to delay collection of some data such as groundwater samples until later phases of investigation. However, to allow focused data collection, it is generally advantageous to begin collection of all necessary data as soon as sufficient information about site conditions is available. Collection of data at the earliest opportunity will minimize the number of phases needed to complete site characterization. It is important to remember that, in the end, the facility design will be evaluated in conjunction with the physical conditions. Because the site design will not or may not be available until the bulk of the site characterization is complete, it will not be possible for the Department to give a definitive statement regarding site characterization early in the process.

The following sections provide an outline of contents for a Phase I or Phase II site characterization work plan. The Phase I site characterization study would be a reconnaissance phase where available information such as topography, surface water, regional geology, regional hydrogeology, and site specific information would be discussed with the Department prior to moving into the next phase of the work plan.

### 4.1 Phase I Site Characterization Work Plan

This section provides a minimal level of detail regarding information that should be included in a Phase I Site characterization work plan.

I. Table of Contents

II. Introduction
- Plan Identification and objectives
- Data quality objectives

III. Summary of Available Information
- Topography
- Surface Water
- Regional Geology
- Regional Hydrogeology
- Site specific information, if any
- Other

IV. Proposed Investigation
- Borings - number, locations, depths

- Field Procedures - drilling and sampling methods, proposed analyses
- Well Installation and development - number, locations, depths, construction, development methods
- Water level measurements - methods, accuracy, frequency, etc.
- Other

V. Schedule

## 4.2 Phase II Site Characterization Work Plan

This section provides a minimal level of detail regarding information that should be included in a Phase II Site characterization work plan.

I. Table of Contents

II. Introduction
- Plan Identification and objectives
- Data quality objectives

III. Summary of Available Information
- Topography
- Historic land use
- Surface Water
- Regional Geology - stratigraphy, lithology, structure, etc.
- Regional Hydrogeology - depth to groundwater, groundwater flow directions, unconfined, perched, confined conditions, etc.
- Phase I results, cross sections, depth to groundwater, groundwater flow directions, lithologies, grain size, etc.
- Other

IV. Proposed Investigation
- Borings - number, locations, depths
- Field Procedures - drilling and sampling methods, proposed analyses
- Well Installation and development - number, locations, depths, construction, development methods
- Water level measurements - methods, accuracy, frequency, etc.
- Aquifer tests - wells, field methods, analytical methods
- Groundwater sampling - field methods, analytical methods, reporting
- Other

V. Schedule

## 5.0 Drilling and Sampling Methods

An exhaustive discussion of drilling and sampling methods is beyond the scope of this guidance. However, the Department believes it is appropriate to include some information related to frequently used methods for site characterization.

Information provided by EPA guidance (1992b) includes the following basic guidance related to selection of drilling procedures (for installation of monitoring wells):

- Drilling should be performed in a manner that preserves the natural properties of subsurface materials;
- The drilling method should allow for the collection of representative samples of rock, unconsolidated materials, and soil;
- The drilling method should allow for collection of representative groundwater samples. Drilling fluids including air should be used only when minimal impact to the surrounding formation and ground water can be ensured.

One important goal of the drilling effort is collection of intact, undisturbed samples for further evaluation. Obviously there are a number of drilling techniques that can be used at any given site; whatever drilling method is selected should be capable of providing intact, undisturbed samples for lithologic description and any other needed evaluation. Two of the more common methods are discussed below.

Hollow stem, continuous flight auger (HSA) drilling is the most frequently employed method of drilling monitoring wells in unconsolidated materials (EPA, 1992b), and is among the most desirable for construction of monitoring wells (Barcelona, et.al., 1985). HSA can also frequently be used in consolidated materials. Use of HSA drilling provides easy use of sampling methods to collect intact samples for lithologic and/or laboratory analysis, such as split spoon samplers, Shelby tubes, and continuous core samplers. Use of HSA eliminates or greatly reduces two problems posed by use of solid stem augers. When using solid stem augers, the augers must be removed from the hole to collect intact samples; this represents additional work and time needed for drilling, and introduces the chance that the hole will collapse when augers are removed. Use of HSA eliminates the need to remove augers from the hole for sampling, and either eliminates or greatly reduces the likelihood that a hole will collapse during soil sampling or well construction. The EPA (1985) notes that the solid stem auger method of drilling is a poor second choice to the more desirable hollow-stem auger methods. The Department recommends that the HSA method of drilling be used unless site specific technical reasons require an alternate method of drilling.

Air rotary drilling is another common method which historically has been frequently used for site investigations at both new sites and impacted facilities. EPA guidance (EPA, 1992b) states that the air rotary drilling method may jeopardize the collection of representative and accurate chemical samples. The guidance also notes that air rotary drilling does not allow collection of representative samples, and therefore, borings cannot be logged with accuracy. Use of air rotary may also mask the presence of thin permeable, saturated intervals, and in some cases, may make difficult the identification of the first occurrence of groundwater in a boring.

## 6.0 Specific information requirements

This section provides information on the minimum information that needs to be collected for adequate site characterization. It is important to understand that every site is unique, and that more information may be needed for any given site than is described here. The design of the site characterization program needs to be coordinated with the Department in advance.

A phased approach incorporating at least two phases of drilling is generally best for characterizing a site. Such a phased approach is assumed for purposes of this guideline. This is consistent with EPA Guidance (1992b, 1991), which indicates that site characterization work should be completed prior to the design and installation of the monitoring well network. In order to determine whether sufficient data of adequate quality has been collected for site characterization, EPA Guidance (1992b) poses three general questions that should be considered when evaluating the information compiled for site characterization:

1. “Has enough information been collected to identify and adequately characterize the uppermost aquifer and potential contaminant migration pathways?”

2. “Does the information allow for the placement of monitoring wells that are capable of immediately detecting releases from the regulated unit(s) to the uppermost aquifer?”

3. “ Have appropriate techniques been used to collect and interpret the information that will be used to support the placement of monitoring wells, and are the quality and interpretation of the information satisfactory when measured against the program’s Data Quality Objectives?”

In general, results from an adequately designed and implemented first round of drilling (Phase I) will be sufficient for a general determination of the suitability of the entire site for waste disposal, in the absence of the discovery of significant variability. Phase I investigations should include borings/wells advanced to a depth of at least 200 feet below the base elevation of waste or ten feet into groundwater, whichever is shallower, at a density of about one per five acres of disposal area. Please note that drilling completed at the suggested density for the first phase of drilling will generally <u>not</u> be sufficient to characterize specific areas of a facility for waste disposal, where a greater density of drilling typically needed. This is especially true for facilities for which an alternative ECS design is proposed.

The design of the site characterization program for Phase II needs to be coordinated with the Department after data from the first drilling are available for review. The Department will evaluate Phase I data, as well as any other available information, and work with applicants to formulate a plan for Phase II characterization. For most sites, the density of borings will be increased for the second phase and subsequent rounds of drilling to refine the understanding of site conditions.

Drilling conducted at facilities around Wyoming has shown that heterogeneous subsurface conditions with relatively abrupt lithologic variations and/or discontinuities may be expected. Such conditions would usually necessitate investigation in greater detail than would be needed for relatively simple subsurface conditions. The following bullets provide guidance regarding some situations which would suggest the need for greater or lesser density of borings/wells during Phase II.

- If there is good lithologic correlation shown by logs from Phase I, fewer borings/wells would be needed in later phases (i.e., tending toward one boring per two acres of waste disposal area). Conversely, non-uniformity in lithologic correlation between borings from Phase I would suggest a need for a greater density of borings.
- The suspected presence of confined or perched groundwater would indicate the need for a much greater boring/well density to demonstrate confining conditions are present or to delineate the lateral extent of perched groundwater throughout the site.
- If significant variation is noted in permeability data, additional drilling would be indicated to delineate lateral and/or vertical extent of zones of differing permeabilities.
- If regional or available site specific data suggests the presence of lithologic discontinuities, a greater density of borings would be indicated.
- Conditions such as steeply dipping beds or fractures would indicate the need for a greater density of borings/wells to characterize changes in lithology and/or variations in permeability.
- For facilities with no apparent groundwater within 200 feet below the base elevation of the disposal area, as demonstrated by properly constructed monitoring wells, and where simple geologic conditions exist, fewer borings may be needed for adequate characterization in any Phase II characterization effort.

In general, for facilities proposing an alternative ECS design, the second phase of drilling will entail substantially more work than would be needed for a facility which will be constructed with an ECS, due to the increased potential for groundwater impacts from a facility with an alternative ECS design.

Site characterization activities need to address two separate but related subsurface intervals. The first interval includes the vadose zone from ground surface to the shallowest groundwater, or a depth of at least 200 feet below the lowest elevation of waste disposal. The second interval comprises the uppermost water bearing zone. Information pertinent to these investigations is described below.

### 6.1 Unsaturated Zone Investigation

A sufficient number of borings and/or test pits should be drilled to adequately characterize subsurface conditions. This includes collection of samples for lithologic description, and laboratory analyses. Information also needs to be collected regarding remolded permeability of the material that will be excavated, stockpiled, and used for final cover.

Intact/undisturbed samples need to be collected at a frequency of at least one sample for each five-foot interval drilled for lithologic description/analysis. <u>Continuous coring of at least one and preferably all borings is desired and strongly advised.</u> EPA guidance (EPA 1992b) indicates that samples should be collected from borings at all suspected changes in lithology, the deepest borehole drilled should be continuously sampled, and recommends that all borings be continuously sampled. Detailed logging of all borings is necessary. It is very important to include information on the color, presence of joints and/or fractures, degree of weathering, and any oxidation coatings or mineralization along joints, fractures, bedding planes, or other openings which may indicate water movement.

For each major lithologic unit encountered in the vadose zone and the uppermost water bearing zone, appropriate samples must be collected for description or analyses, such as Unified Soil Classification System (USCS) for unconsolidated materials, American Geological Institute (AGI) for consolidated materials, permeability, grain size analysis, porosity, dry bulk density, moisture content, plasticity, and other analyses as needed. If unconsolidated and consolidated materials are present, samples must be collected from both types of material so that both can be characterized. Similarly, if wide lithologic variations are present in consolidated materials, samples must be collected to characterize each type. Please refer to Appendix A for a list of potentially applicable analyses and analytical methods.

In order to identify final cover requirements, sufficient samples must be collected to adequately characterize undisturbed permeability immediately below the base elevation of disposal areas and across the footprint of disposal areas. Remolded permeability of material that will be used for final cover needs to be determined. Please see other Department guidance regarding final cover specifications for additional information. Also, if an applicant is anticipating use of an alternative earthen final cover, they should collect site specific information related to water retention capacity of the soil to be used in the final cover. The Department needs to be consulted before beginning this work.

An applicant who is considering requesting approval for an alternative design needs to identify additional data needs for fate and transport modeling prior to fieldwork, if the number of iterations of fieldwork is to be minimized. Additional analyses that are needed include, but are not limited to, organic carbon content, cation exchange capacity, and site specific distribution coefficient ($K_d$) values. See Section 6.3 for additional information.

### 6.2 Groundwater Investigation

A minimum of three wells need to be completed in the shallowest water-bearing-zone beneath the facility in order to determine groundwater flow direction. More than three wells will be needed for large sites and/or sites where the hydrogeology is complex, such as sites where perched groundwater or groundwater divides are suspected or have been identified. At new facilities these initial wells need to be capable of monitoring the area that will be first used for disposal. For example, if a 100-acre site is being permitted, but only 20 acres will be used in the first 20 years, at least three wells are needed in the 20 acre area to define the groundwater flow direction. As previously mentioned, if shallow groundwater is not encountered, wells should be drilled to a depth of at least 200 feet below the base elevation of waste disposal. Monitoring wells need to be completed at this depth and maintained for the life of the facility even if groundwater is not encountered during drilling, to periodically check for the presence of groundwater throughout the life of the facility. This is necessary because historic data for a number of sites in Wyoming show that monitoring wells that were dry for several months or years suddenly developed several feet of groundwater. In other instances, significant increases in groundwater elevations, on the order of 10 to 15 feet have been observed. Unacceptably low waste to groundwater separation distances, or intrusion of groundwater into waste may occur as a result of such increases.

When groundwater appears to be absent at a site to a depth of 200 feet below the base of wastes, wells installed to monitor this condition should be screened across as great an interval as possible. This will allow for a demonstration of the absence of groundwater throughout the life of the facility. If groundwater does appear at a later date, the well(s) with overly long screened intervals will need to be abandoned and replaced by properly constructed wells.

Monitoring wells constructed in the uppermost water-bearing zone need to have screen lengths limited to about ten to fifteen feet. Screen lengths greater than fifteen feet will be considered by the Department on a case-by-case basis. In all cases, screens must be installed such that cross communication between water bearing zones does not occur, i.e., installed so that screens do not cross confining layers or penetrate perched zones, and the annular space above and below the screen is sealed. If the uppermost groundwater zone is very thick (greater than 20 to 30 feet), nested wells will likely be needed to determine whether vertical hydraulic gradients are present.

The groundwater portion of the site characterization will need to gather adequate data to determine whether unconfined or confined groundwater conditions (or both) are present. The physical characteristics and lateral extent of suspected or confirmed perched water bearing zones needs to be defined. EPA guidance (1992b) states that owners and operators should be aware that true confining layers rarely exist, and that facies changes are the rule and not the exception at most sites, which may preclude the existence of a confining layer. EPA guidance goes on to note that even if a confining layer is continuous (it usually is not), and a solvent dense non-aqueous phase liquid (DNAPL) plume is present due to a release, the solvent may interact with clays in the confining layer causing desiccation and formation of fractures. Thus, in the event of a significant release, the confining layer may not prevent contaminant migration.

At sites where the uppermost water bearing zone appears to be confined, nested wells need to be installed to make an accurate determination regarding the presence of confined groundwater. The absence of groundwater in a shallow interval during drilling, with subsequent detection of groundwater in the same interval, does not, in and of itself, provide sufficient evidence of confined groundwater. To confirm confined conditions, a deeper well needs to be constructed, screened only in the interval suspected of being confined, and sealed across the upper confining layer. A second shallower well should exhibit a significant head difference, and, potentially, different groundwater chemistry, if confining conditions are present. Also, geologic conditions, such as the presence of confining layers, orientation and dip of beds, etc. will need to support the interpretation of confined groundwater. While the Department will consider head differences as supporting evidence for confined conditions, potential problems are acknowledged interpreting head differences, such as in groundwater discharge areas. Determination of hydraulic properties, such as the coefficient of storage, may also provide supporting evidence for identification of confined conditions (Lohman, 1979, Driscoll, 1986). Physical evidence of the presence of a confining layer should be provided in the form of undisturbed samples of the lithology in the confining layer. Finally, the physical characteristics and lateral extent of any confining layers must be defined. The Department would stress that proper well construction techniques are especially important in cases of confined (or perched) groundwater, to prevent the potential for contaminant migration in the event of a release.

The Department has identified several different uses or interpretations of the term perched groundwater in Wyoming. In the past this has lead to misunderstandings related to what is meant by the use of the term perched groundwater. For the purposes of this guideline perched groundwater will be defined as:

> *Groundwater that is not confined and is separated from an underlying main body of groundwater by an unsaturated zone* (EPA, 1992a).

The physical characteristics and lateral extent of suspected or confirmed perched water bearing zones needs to be defined. When perched groundwater is present, a greater number of monitoring wells will be required to ensure that the monitoring network is capable of detecting a release from the facility.

When groundwater is present, slug tests, either slug in or slug out, or other aquifer tests such as packer tests, pump tests, etc. need to be conducted on sufficient representative wells in each lithologic type encountered to provide estimates on the range of hydraulic conductivity of water-bearing intervals. A sufficient number of groundwater samples need to be collected and analyzed to provide information on ambient groundwater chemistry before wastes are placed (Chapter 2 Section 2 (b)(iii)(A)(IX)(6) of the SWRR). When groundwater samples are analyzed, detection limits achieved need to be as low as possible under routine laboratory conditions, and must be at least as low as maximum contaminant levels or other levels of concern such as groundwater protection standards established by the administrator.

### 6.3 Alternative Design Demonstration Information

In recognition of the large number of municipal landfills that have caused groundwater contamination problems nationwide, in 1989 the U.S EPA implemented regulations at the national level requiring ECS for new landfills. In parallel with requirements at the national level, the Wyoming SWRR were modified in the early 1990s to require engineered containment systems (liner and leachate collection systems) for new Type I landfills and new cells or lateral expansions at existing Type I landfills. The SWRR do allow the Department to approve alternative designs that do not include ECS under certain conditions. Information regarding the alternative design demonstration process, and specific data needs for an alternative demonstration are presented in another Department guidance document.

If an applicant is considering proposing an alternative design demonstration, during the site investigation sufficient site specific data to support the alternative design must be collected. In order to minimize the need for multiple field mobilization efforts the information needed for a successful alternative design demonstration is mentioned here. See other SW guidance for additional information on alternative design demonstrations. The types of site specific sample data needed include, but may not be limited to:

**Vadose Zone** (data to be collected for each lithologic type encountered in vadose zone)**:**

- Percentages of sand, silt, and clay (as individual components)*****
- Total Organic Matter (TOM) (TOM = TOC X 1.724) *
- Iron *****
- Aluminum *****

- Total Porosity *****
- Field Capacity *****
- Saturated Hydraulic Conductivity *****
- Dry Bulk Density *****
- Thickness of lithologic intervals
- Depth to groundwater

**Aquifer:**

- Percentages of Sand, Silt, and Clay (as individual components)*****
- Total Organic Matter (TOM) (TOM = TOC X 1.724) *****
- Iron *****
- Aluminum *****
- Groundwater pH ( determined during field sampling)
- Total Porosity *****
- Effective Porosity *****
- Darcy Velocity
- Thickness
- Dry Bulk Density *****
- Hydraulic Conductivity

  * as determined by laboratory analyses.

## 7.0 Reporting

A thorough, detailed, and comprehensive report of subsurface conditions needs to be presented in the permit application. Reports must be prepared by qualified professionals in compliance with Wyoming statutes. In general, reports need to include:

**Regional geologic information, such as:**

- Summary of stratigraphy (i.e., formations, lithologies and thicknesses) and structure (folding, faulting, strike and dip).
- Summary of hydrogeology (i.e., aquifers, water quality, recharge and discharge areas, flow directions, thickness, porosity, hydraulic conductivity, etc).
- Copies of all available well logs for water wells within one (1) mile of the site are required as supporting documentation (a computer printout from the State Engineer's Office is useful in identifying all wells within one (1) mile of the site).
- A geologic map, stratigraphic section and cross-section(s) are required as supporting documentation.

**Site-specific geologic information, such as:**

- A detailed summary of any supporting documentation such as site-specific geologic reports, with the entire report included as supporting documentation
- Summary of stratigraphy (i.e., formations, lithologies and thicknesses) and structure

(folding, faulting, fracturing, strike and dip).

- A geologic map, stratigraphic section and cross-section(s) as supporting documentation (color or unique patterns are preferable).
- Maps and cross-sections showing distribution of different lithologies. Maps need to be constructed using standard scales, with north arrows, appropriate topographic contours, and explanation blocks that contain explanations for all symbols/line weights shown on the map.
- Cross-sections showing lithologic relationships from multiple directions. Fence diagrams may be preferable.

**Site-specific soil data, such as:**

- USCS soil descriptions.
- Applicable properties of unconsolidated material such as grain size distribution, permeability, dry bulk density, moisture content, organic carbon content, and porosity.
- Thickness and areal extent of all soil types (isopach map may be necessary as supporting documentation).
- Description of consolidated and unconsolidated materials including consistency and distribution of unconsolidated material (i.e., alluvium, colluvium and soil), depth to consolidated material (i.e., bedrock), and characteristics of bedrock and bedrock discontinuities such as faults, fractures, joints, etc.

**Unstable area information, such as:**

- Delineation of unstable areas caused by natural features or man-made features or events, and which may result in geologic hazards including but not limited to slope failures, landslides, rockfalls, fracturing from blasting activities if any, differential and excessive settling or severe erosion.
- A discussion of trench wall design in light of any unstable areas identified.

**Information on seismic zones, wetlands, and floodplains:**

- Delineation of any seismic zones, wetlands, or floodplains which are present.
- Seismic impact zones using USGS data.
- Wetlands delineation needs to be supported by documentation identifying the presence or absence of wetlands, completed in accordance with the U.S. Army Corps of Engineers *Wetlands Delineation Manual* - 1/87 (AD/A176 734).
- A map identifying the location of any fault areas, 100-year floodplains or wetlands needs to be provided as supporting documentation.

**Information related to site-specific groundwater occurrence:**

- Characterization of uppermost groundwater, including depth to groundwater, groundwater elevations, flow direction(s) and rate, thickness of uppermost water-bearing formation, and hydraulic conductivity.

- Potentiometric surface maps for each ground water zone identified.
- Potentiometric surfaces shown on site-specific cross sections.
- Relationship between geologic formation(s) and water bearing zones (e.g., does groundwater flow across bedding, or is groundwater flow controlled by lithology).
- Hydraulic connections between saturated zones if more than one zone is identified, porosity, saturated hydraulic conductivity, for each water-bearing zone encountered.
- Discussion of any perched or confining conditions identified, including location, lateral and vertical extent of any impermeable layers, with supporting documentation of lithology, and permeability.
- Groundwater recharge and discharge areas, if any.
- Amount and causes of groundwater level fluctuations and flow pattern variations for each groundwater zone (e.g., seasonal variations, offsite/onsite well pumping).
- Groundwater/surface water interconnections, if any.
- Copies of any and all supporting documentation such as site-specific groundwater reports.

**Information related to site-specific groundwater quality:**

- Identify seasonal and spatial variations in groundwater quality (if present).
- A minimum of four (4) groundwater samples from each well (upgradient and downgradient) are required to define baseline groundwater quality and to support interwell statistical analysis
- A minimum of eight (8) baseline groundwater samples are required from each well to support intrawell statistical analysis.
- Additional samples may be needed depending on the distribution of the data and the requirements of the statistical methods.
- Laboratory reports must be provided as supporting documentation.

In all cases, supporting documentation needs to be provided as an exhibit or appendix and needs to be properly referenced in the permit application narrative.

## 8.0 Professional Geologist Certification

Geological services or work must be stamped, signed, and dated by a professional geologist (see W.S. § 33-41-115).

## 9.0 Further Information

Further information or clarification can be obtained from the following Solid and Hazardous Waste Division offices. Comments and suggestions for improvements are always appreciated.

Casper : (307) 473-3450
Cheyenne : (307) 777-7752
Lander : (307) 332-6924

## 10.0 References

Information and concepts in the following guidance documents and technical references were considered in development of this guidance, or may be of interest to users.


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## 11.0 Guideline Approval

I have reviewed and approved the policies and procedures described in this guidance document.

Signed

7/21/09

Carl Anderson
Administrator
Solid and Hazardous Waste Division
Department of Environmental Quality

Date

**Attachments**

Appendix A "Methods for Laboratory Analysis" (June 11, 2009)

**Guideline History**

| | |
|---|---|
| August 22, 2002, | Work Group Draft Version 1 - DO NOT CITE |
| June 6, 2003 | Work Group Draft Version 2 - DO NOT CITE |
| December 17, 2003 | Draft Version 3 - DO NOT CITE |
| June 23, 2009 | Final Version |

**Solid Waste Guideline #17 Appendix A**
**“Methods for Laboratory Analysis”**
**June 23, 2009**

| Analysis | Methods |
| --- | --- |
| Sieve Analysis | ASTM D1140, D422 |
| Total organic carbon | ASA Monograph No. Method 29-3.5.2, ASTM D2974-00, |
| Fe, Al | 6010 |
| Dry Bulk Density | Calculation |
| Total Porosity | Calculation |
| Permeability - field | D4630-96, D4630-95, D5084, Bureau of Reclamation, D3385-94 |
| Permeability - lab | ASTM D5084, D4630-96 (2002), D2434-68 (2002) |
| Field Capacity | D2325-68 (2000), D3152-72 (2000), ASA 36-2.2.2, ASA 36-4.2 |
| Moisture Content | ASTM D2216-98, D4643-00, D4959-00 |