MDE

MARYLAND DEPARTMENT OF THE ENVIRONMENT
Water Management Administration

INDIVIDUAL SEPTIC SYSTEMS
AND WELLS PROGRAM

SITE EVALUATION TRAINING MANUAL FOR ON-SITE SEWAGE TREATMENT AND DISPOSAL SYSTEMS

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ABSTRACT

This manual presents a procedure for determining the suitability of a site for an on-site sewage treatment and disposal system. The manual was developed for use in site evaluation training courses sponsored by the Maryland Department of the Environment (MDE). The site evaluation procedure is divided into four major steps that include application submittal and review, preliminary evaluation, field investigation and suitability recommendations. Each step is described, and recommended standard procedures, forms, charts and checklists are provided. The procedures presented in the text are generalized in order to have a wider applicability throughout the State and are not mandatory except when required by regulation. Appendices contain lists of applicable regulations and guidelines; references for additional reading; a glossary; and forms, tables, methods and additional information necessary to conduct site evaluations and meet minimum State regulatory requirements.

ACKNOWLEDGEMENTS

Three groups were involved in the preparation of this manual: (1) Maryland Department of the Environment Contract Supervisors, (2) Authors, and (3) Technical Reviewers. Contract supervision was provided by Jay Prager and Jane Gottfredson of the Maryland Department of the Environment (MDE). The manual was developed under a contract with the Maryland Center for Environmental Training (MCET) with administrative supervision and final editing provided by MCET Director, Jake Bair, and MCET Special Projects Manager, Laura Ford. Typesetting, proofreading and design were provided by Julia Lannon. The manual was written by Clifford Stein from Earth Data Incorporated through a subcontract with MCET. Technical review was provided by MDE staff, including the contract supervisors and Wayne Asplen, John Covalt, William Forlifer, Barry Glotfelty, Don Hammerlund, David Kerr and C.T. Tien.

Much of the material presented in this manual was adapted from existing MDE site evaluation courses and from papers, manuals, guidelines and regulations published by the U.S. Environmental Protection Agency, U.S. Department of Agriculture–Soil Conservation Service (USDA–SCS), and the States of Delaware, Pennsylvania, Virginia and Wisconsin.

SITE EVALUATION MANUAL FOR ON-SITE SEWAGE TREATMENT AND DISPOSAL SYSTEMS

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1.0 INTRODUCTION

1.1 BACKGROUND

The primary responsibility for granting permits for on-site sewage disposal systems is governed by State of Maryland regulation and is administered by delegated authority to local health departments or environmental agencies from the Secretary of the Maryland Department of the Environment (MDE). The primary objectives of the permitting program are to protect the public health and to prevent pollution and unacceptable degradation of surface and groundwaters of the State. Protection of public health includes determining that a site will have a safe and adequate sewage disposal system and water supply.

Conventional on-site systems commonly consist of a septic tank and subsurface soil absorption system. The septic tank is designed to receive raw sewage and provide primary settling and storage of solids and limited anaerobic digestion prior to discharge to the soil absorption system. The soil absorption system commonly consists of a gravity flow piping distribution system and a series of shallow or deep gravel-filled trenches or seepage pits. The partially-treated septic tank effluent moves through the infiltrative surfaces of the soil absorption system and receives additional treatment and renovation as it percolates through the surrounding soil and mixes with underlying groundwater. Sand mounds, elevated beds, sand-lined trenches and bermed infiltration ponds may be used where appropriate to overcome site limitations involving high water tables, shallow depths to bedrock and slowly permeable soils.

The performance of an on-site sewage disposal system depends primarily on the ability of the soil at the site to transmit and renovate applied wastewater. On-site sewage disposal systems that are properly sited, designed, constructed, operated and maintained can be a reliable and cost-effective method of treatment and disposal of sewage in rural and low-density suburban areas.

1.2 PURPOSE

This manual presents a generalized procedure for determining the suitability of a site for an on-site sewage treatment and disposal system and has been prepared for use in site evaluation training programs sponsored by MDE. The procedure involves a systematic four step process for collecting and evaluating data to determine if a site meets the minimum State regulatory criteria for approval of an on-site sewage treatment and disposal system.

The four major steps of the site evaluation process are:

1) Application Submittal and Review;

2) Preliminary Evaluation;

3) Field Investigation; and

4) Suitability Recommendations.

Special emphasis in this manual is given to standard methods used by soil scientists for examining and describing site landscape features and soil morphological and physical properties that influence the soil's ability to transmit and adequately treat or renovate applied wastewater.

1.3 SCOPE

This manual was prepared for introductory site evaluation training programs sponsored by MDE. The training programs are provided for Department and local approving authority staff responsible for implementing State regulations and supervising or conducting site evaluations. Although the training programs are introductory, many of the procedures for describing soils require considerable training and field experience to master and to apply to evaluating sites for on-site sewage disposal. The users of this manual are encouraged to supplement the introductory training material with additional reading and advanced courses. APPENDIX A contains a list of references suggested for additional reading.

This document applies primarily to site evaluations for residential on-site sewage treatment and disposal systems. In many areas of the State, local approving authority site evaluation requirements are the same as minimum MDE requirements. However, local authorities can be more stringent than MDE, and users of this manual should check with local authorities to determine all applicable regulations, ordinances, guidelines and policies.

The four basic steps of the site evaluation process for larger commercial and community systems are generally the same as for smaller residential systems. More detailed soil–hydrogeologic field investigations and impact analyses, however, are typically required to determine site suitability and provide data for permit approvals and design. Users of this manual are referred to MDE *Guidelines for On-Site Community Systems and Multiple Use Sewage Systems with Accumulative Flow Exceeding 5000 Gallons Per Day* for additional information (see APPENDIX B for a list of applicable State regulations and guidelines).

2.0 SITE EVALUATION PROCESS

2.1 INTRODUCTION

Regulations require that a person may not construct or alter a residence, floating home or commercial establishment, served or proposed to be served by an on-site sewage disposal system and private water supply system, until the local approving authority either (1) has issued both an on-site sewage disposal permit and a well construction permit or (2) has certified that the existing system is adequate [*Code of Maryland Regulations (COMAR),* 1992]. Before issuing an on-site sewage disposal permit, a detailed site evaluation must be conducted. A properly conducted site evaluation provides sufficient information to select the most appropriate sewage treatment and disposal system from a range of feasible alternatives.

A detailed site evaluation considers topography, soils, geology, surface and subsurface drainage, usable area and groundwater conditions, in conjunction with local records and percolation tests or other tests used to estimate soil hydraulic properties. Sufficient area must be available to support the proposed use of the property and to allow for construction of the required systems. Personnel who conduct site evaluations must understand and communicate to the applicant and general public that a site evaluation is a comprehensive process that consists of a number of steps and is more than just a percolation test.

2.2 OBJECTIVES

The main objectives of the site evaluation process are to determine if a site meets regulatory requirements and to help ensure that, when a site is approved, the on-site sewage disposal system will perform hydraulically, the soils at the site will provide adequate treatment of applied wastewater, and the sewage disposal area (SDA) will be adequate. The SDA is that area on the property where the initial and subsequent repair on-site sewage disposal systems will be installed.

2.2.1 Regulatory Requirements

Site criteria and design requirements that determine site suitability are provided in State regulations and guidelines. A list of all applicable State regulations and guidelines that directly govern on-site sewage disposal systems is presented in APPENDIX B. Site criteria and design requirements are summarized below:

1) Land with slopes greater than 25 percent, land classified as man-made fill, land classified as floodplain soils or land designated as an easement, right-of-way, driveway, building site or other prohibited zone cannot be used for sewage disposal or delineated as an SDA.

2) SDAs must meet all minimum horizontal separation distances from steep slopes, seepage areas, springs, drainage ditches, surface water bodies, drainageways, gullies, rock outcrops, flood plain soils, wells, buildings and property lines.

3) SDAs for lots legally established prior to November 18, 1985 without regulatory approval must be sized to accommodate a minimum of two complete systems.

4) SDAs for lots that were approved by appropriate regulatory authorities as of November 17, 1985 must be sized to accommodate a minimum of two complete systems. However, if the lot SDA was approved subject to 10,000 $ft.^2$ or greater, the original approval conditions will remain in effect.

5) SDAs for new construction on lots approved after November 17, 1985 must be sized to accommodate a minimum of three complete systems or 10,000 $ft.^2$, whichever is the larger.

6) Site evaluations are restricted to the wet season (i.e., February to April) for soils with seasonal perched or seasonal high water tables based on USDA–SCS soil survey maps or site-specific soil conditions.

7) Representative soil profile descriptions and field data must be collected from the SDA to demonstrate that a minimum of 4 feet of suitable unsaturated and unconsolidated soil material (i.e., soil treatment zone) exists between the deepest proposed disposal system infiltration surface and seasonal high groundwater, regardless of the time of the year the evaluation is conducted.

8) Variances to the 4 foot soil treatment zone requirement are allowed in some system repair situations and in areas designated in a county Groundwater Protection Report.

9) Sufficient acceptable percolation tests or other approved tests must be conducted within the SDA at the depth of the proposed disposal system infiltration surface. Standard percolation test rates for trench systems must be between 2 and 30 minutes per inch. Infiltrometer test rates for sand mounds must be between 2 and 60 minutes per inch and conducted in the least permeable horizon or layer in the upper 24 inches of the soil. In the Coastal Plain, percolation rates faster than 2 minutes per inch may be acceptable, if deemed appropriate by the approving authority.

10) Design flows for sizing residential systems are computed based upon a minimum of 150 gallons per day per bedroom. Calculations for determining a nitrogen balance and hydrologic balance can use 75 gallons per day per bedroom (primarily when large flow systems are being considered).

11) State regulations provide for the use of innovative and alternative technology or experimental designs to correct existing system failures, and for new construction on legally established lots under certain conditions.

12) Design flows for sizing non-residential facilities are computed based upon regulation and the best available water usage information. When water usage information is not available, maximum daily flows in accordance with State regulations and available guidelines are used for system sizing. Average daily sewage flow can be used in determining a nitrogen balance and calculating a hydrologic balance. Average daily sewage flow is defined as 50 percent of the design maximum daily wastewater flow.

In addition to MDE regulations and local ordinances that govern on-site sewage disposal systems, other County, State and Federal regulations involving Chesapeake Bay critical areas, floodplains, stormwater management practices, tidal and non-tidal wetlands, waterways, forest conservation areas, resource protection areas and well head protection areas may impact site feasibility and the location of sewage disposal systems.

2.2.2 Hydraulic Performance

An on-site sewage disposal system is considered to be functioning hydraulically when applied wastewater moves across infiltrative surfaces and through the surrounding soil at rates that equal or exceed the application rate of the partially-treated septic tank effluent.

In many on-site systems, movement of wastewater at the infiltration surface is reduced through time as a result of clogging by biological and chemical processes, or by soil smearing, migration of fines and compaction during construction (U.S. EPA, 1980; McGauhey et al., 1958; McGauhey and Krone, 1967; Bouma et al., 1972; Bouma, 1975; Reneau et al., 1989). If the infiltration rate is reduced to the point where it is consistently less than the daily hydraulic loading rate, continuous and increasing levels of effluent ponding may lead to system hydraulic failure with raw sewage or partially-treated effluent breaking out on the surface or backing up into the building. Hydraulic failure may depend on a number of factors including:

- wastewater characteristics and volume;
- soil and clogging mat hydraulic properties;
- system size and design factors;
- depth of effluent ponding;
- seasonal fluctuations of groundwater;

- depths to restrictive layers; and

- seasonal soil moisture conditions.

Some research suggests that equilibrium conditions and long-term wastewater acceptance rates can be used, along with proper site evaluations, to design systems that will perform hydraulically (Reneau et al., 1989; Healy and Laak, 1974).

2.2.3 Adequate Treatment

Soil can be an excellent treatment medium for most pollutants found in domestic sewage. Physical, chemical and biological processes operating in the soil provide treatment of applied wastewater and, under the proper conditions, can produce water of acceptable quality for discharge to groundwater. Treatment and renovation of domestic wastewaters are primarily related to site-specific soil hydraulic and chemical properties. The treatment mechanisms that operate in the soil include:

- physical filtration;

- ion exchange;

- sorption and precipitation;

- microbial competition or biochemical degradation; and

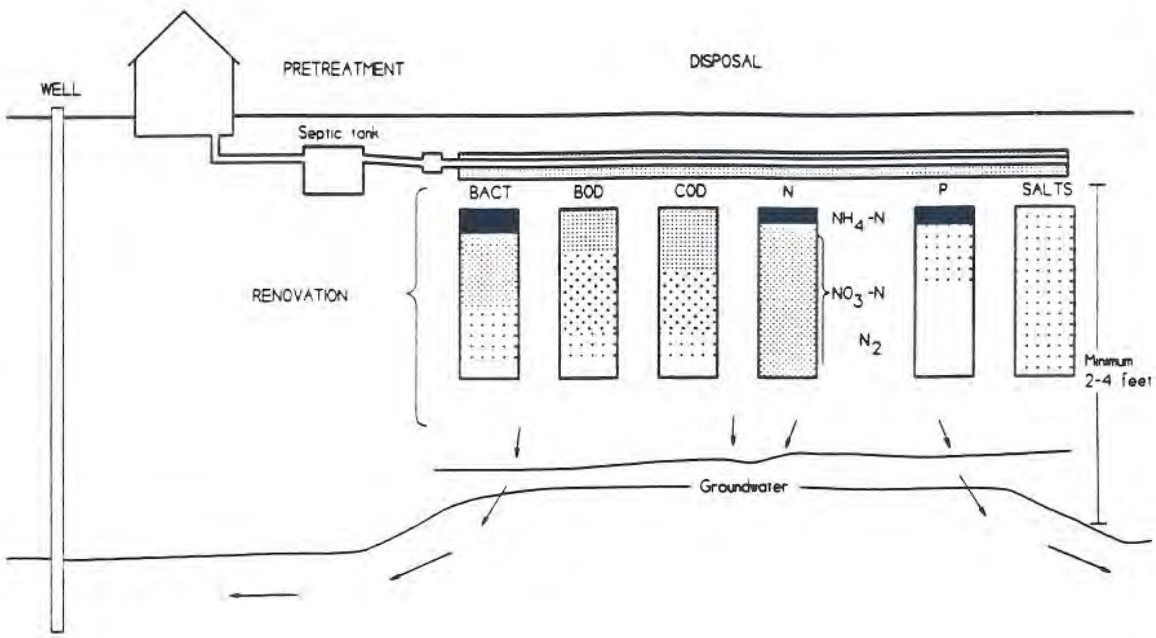
- volatilization and oxidation–reduction.

A list of references that describe in detail the soil as a treatment medium and provide information on the fate and transport of septic tank effluent in soil–groundwater systems is given in APPENDIX A.

Available data and research indicate that a layer or zone of suitable, unsaturated soil material, 2 to 4 feet in depth below system infiltrative surfaces, will provide a high degree of treatment of septic tank effluent (Bouma et al., 1972; Bouma, 1975; U.S. EPA, 1980; Reneau et al., 1989). It has been reported that almost complete removals of COD, BOD, suspended solids, phosphorus and bacterial contaminants can be achieved. Data to support similar reduction of viruses are not as conclusive (Yates and Yates, 1989). Removals and inactivation of viruses are more variable and depend on a number of conditions such as the types of minerals, soil clay content, organic matter, pH, moisture content, residence time in the unsaturated soil and natural die-off of viruses. The use of a 4 foot treatment zone in State regulations helps to compensate for expected errors in estimating depths to seasonal water tables and contractor errors during trench installation.

Other chemical constituents of sewage such as nitrogen, exchangeable cations, chlorides, sulfates, sulfides, trace organics and other anions undergo various reactions in the soil and may be attenuated

ON-SITE SEWAGE DISPOSAL SYSTEM



(Bouma et al., 1972, as modified by Miller, 1976.)

Note: Diagram illustrates that most contaminants of concern, with exception of nitrogen and salts, generally undergo complete renovation.

FIGURE 2.1

Relative degree of renovation of major contaminants in septic tank effluent as they move through suitable soils.

to different degrees. Many of these chemical constituents are not completely attenuated and over time will move downward with soil waters and mix with underlying groundwaters. Increases in total dissolved solids, chlorides and nitrate–nitrogen of groundwaters may be experienced. Additional attenuation, dispersion and dilution tend to reduce the concentration of these constituents as they move away from the disposal site in the groundwater flow system. Recent studies of on-site disposal systems have detected the presence of volatile organic chemicals in residential sewage, septic tank effluent and in underlying groundwater, with potential public health hazards (Greer, 1987; Hathaway, 1980; Tomson et al., 1984; Sauer and Tyler, 1991; Canter and Knox, 1985; Canter, Knox and Fairchild, 1987). The significance of these impacts and the resulting degradation of groundwater quality becomes more important as densities of on-site systems increase. FIGURE 2.1 illustrates

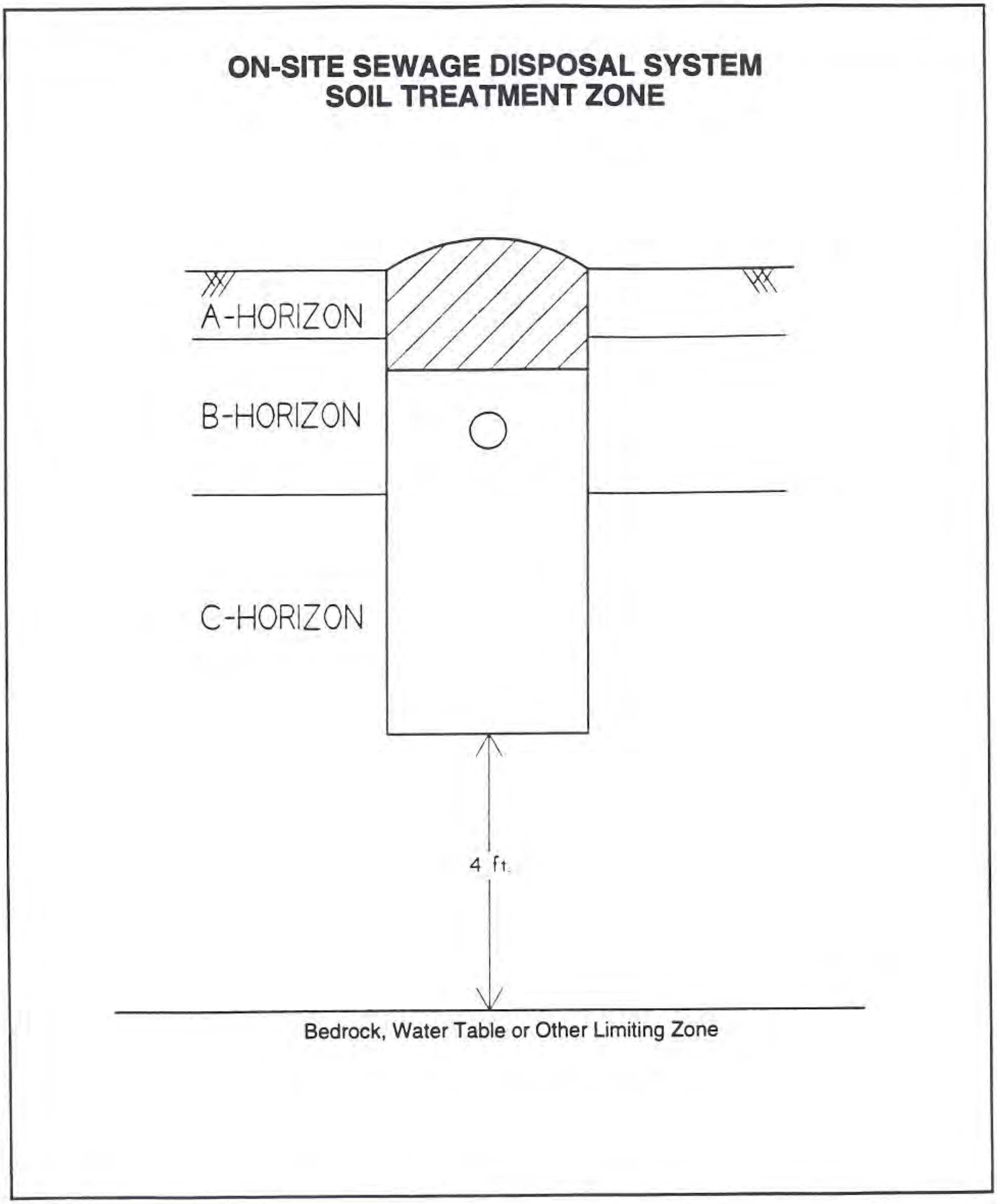


FIGURE 2.2
Required soil treatment zones below a typical trench system.

the basic components of an on-site sewage disposal system and the relative degree of treatment of septic tank effluent in underlying suitable soils.

State regulation requires a soil treatment zone of 4 feet above the maximum height of groundwater or fractured rock and horizontal separation distances from surrounding features to help address the issue of adequate treatment and the protection of surrounding groundwater users and surface water resources. FIGURE 2.2 illustrates the soil treatment zone location for a trench sewage disposal system and TABLE 2.1 presents the horizontal separation distances required by State regulation.

2.3 PROCESS STEPS

The site evaluation process can be divided into four basic steps. The steps include:

1) Application Submittal and Review;

2) Preliminary Evaluation;

TABLE 2.1

HORIZONTAL SEPARATION DISTANCES BETWEEN ON-SITE SDAs AND SURROUNDING SITE FEATURES

FEATURE	HORIZONTAL SEPARATION DISTANCES (ft.)
Slopes >25%	25
Springs and Seepage Areas	25
Drainageways and Gullies	25
Flood Plain Soils	25
Rock Outcrops	25
Stream	100
Well System in Unconfined Aquifer	100
Well System in Confined Aquifer	50
Water Supply Reservoir High Water Elevation Determined by Spillway Crest	300
Stream Tributary to Water Supply Reservoir	200

SOURCE: *COMAR* 26.04.02 (1992).

3) Field Investigation; and

4) Suitability Recommendations.

The following chapters describe each step in detail and provide recommended standard procedures, charts, forms and checklists that can be used by local approving authorities to conduct site evaluations, describe soils and landscapes and make suitability recommendations. A glossary of terms is given in APPENDIX C. This glossary includes terms commonly used in soil science for describing soils and other terms associated with on-site sewage disposal systems and site evaluations. Glossary definitions should always be supplemented by additional reading and study.

3.0 STEP 1: APPLICATION SUBMITTAL AND REVIEW

3.1 OBJECTIVES

The main objectives of this step in the site evaluation process are to determine if an evaluation of the site is appropriate and, if appropriate, to provide the applicant with information on testing requirements and scheduling. Some sites may be eliminated at this step without the need for additional data collection or detailed field investigations. Therefore, this step can produce a savings in both time and cost for the applicant and the local approving authority if it is determined that a site evaluation is not appropriate.

3.2 APPLICATION SUBMITTAL

The first step in the site evaluation process involves the submittal of an application by the property owner or an applicant who may be the owner's agent, a developer or a prospective buyer. The application must be in a form suitable to the local approving authority and should provide at a minimum the following general information:

1) Owner's name, address and telephone number.

2) Applicant's name, address and telephone number.

3) Property data that include directions to the site and sufficient tax map information to accurately locate the site and determine the acreage of the parcel and all proposed lots.

4) Data on existing residences or commercial usage and existing water supply and sewage disposal systems.

5) Data on proposed residences or commercial usage and associated water supply and sewage disposal facilities.

6) Site plan showing the property lines; general topography; the on-site location of existing or proposed wells, septic tanks, sewage disposal areas, streams, springs, buildings, utilities, easements, right-of-ways, driveways or roads; and any existing off-site buildings, wells, septic tanks, sewage disposal systems and streams or water bodies within 100 feet of the property lines.

7) Signature block for owner or applicant stating that information is true and correct.

8) Fee receipt block, for official use only, indicating total fees paid.

9) Application review block, for official use only, that provides summary of information used to approve or deny application.

The application form must be complete in order to conduct the review. An application should not be considered complete until an acceptable site plan is attached, the required fee is paid and the application is signed by the owner, the owner's agent or the applicant. Incomplete applications should be returned for additional information.

A completed example application form is shown in FIGURE 3.1 and a blank example application form is given in APPENDIX D. FIGURE 3.2 shows an example site plan. This example is designed to illustrate the contents of a comprehensive application form and to be used in training exercises. Official forms acceptable to local approving authorities may differ from the example form.

3.3 REVIEW PROCEDURES

Once the application form is complete the review process can begin. Property data and tax map information should be reviewed first to determine the location of the property. After the property is accurately located, the County water and sewer plan must be checked to determine conformance.

If the property and proposed facilities conform to the water and sewer plan, planning and soil survey maps showing areas where sewage disposal systems are prohibited must be checked. Prohibited zones, for example, may include flood plain soils and flood-prone land areas as shown on USDA soil survey maps, resource protection zones, well head protection areas or 100 year flood plain delineations. A list of floodplain soils and flood-prone land areas mapped in Maryland by the USDA–SCS is given in APPENDIX E. If no prohibited zones are present, local records should be checked to determine if previous site evaluations have been conducted and whether additional work is appropriate.

If it is determined that a site evaluation is appropriate, USDA–SCS soil survey maps and supplemental local approving authority lists must be checked to determine if soils are restricted to wet season (i.e., February to April) testing periods.

After the application is reviewed, the applicant will be informed of the decision. If the application is acceptable, the applicant will be provided with information on site evaluation and testing requirements and instructions for site preparation and scheduling. As noted above, testing may be restricted to the wet season.

An application may be tentatively rejected at this step for the following reasons:

1) Proposed project is not in conformance with the approved county water and sewer plan.

MARYLAND DEPT. OF THE ENVIRONMENT ONSITE SEWAGE DISPOSAL PERMIT SITE EVALUATION REPORT APPLICATION FORM				FILE NO.	WO-200-SE-90		
				MD. GRID:	N180/E1340		
				COUNTY:	WORCESTER		
				TAX MAP/B/P:	103/B/65		
				SUBDIVISION:	HILLTOP		
OWNER NAME	JOHN DOE JR.			APPLICANT	SAME		
ADDRESS	101 HILLTOP LANE			ADDRESS			
	ANYWHERE,MD.						
TELEPHONE	410	631	3652	TELEPHONE			
PROPERTY DATA							
PROPERTY	SAME			DIRECTIONS			
ADDRESS				S/S HILLTOP LANE @ 1 MILE WEST OF RT.2			
TAX MAP NO.	103	BLOCK	B	PARCEL NO.	65	PARCEL SIZE	4.5 ACRES
SUBDIVISION	HILLTOP			SECTION	1	TAX ACCT. NO.	UNKNOWN
LOT NO.	2	LOT SIZE	1.4 ACRES				
EXISTING FACILITIES							
SITE TESTS	(Y) / N	FILE NAME –		JOHN DOE SR.		AUG.1958	
ONSITE WELL	(Y) / N	DESCRIPTION–		DEPTH (ft)	100	PUBLIC WATER	Y / (N)
RESIDENCE	(Y) / N	OCCUPIED	(Y) / N	BEDROOMS	3	TOTAL SQ.FT.	2000
PLUMBING	(Y) / N	DISPOSAL SYSTEM TYPE–			SHALLOW	TRENCH	
COMMERCIAL	Y / (N)	EXISTING USE–		N/A			
PROBLEMS	(Y) / N	DESCRIPTION –		SURFACE	FAILURE IN	WINTER	
VEGETATION AT SITE		WOODED	Y / N	OPEN	(Y) / N	CROPS	Y / N
PROPOSED FACILITIES							
CONSTRUCTION TYPE		NEW	(Y) / N	ADDITIONS	Y / N	REPAIR	Y / N
ONSITE WELL	(Y) / N	DESCRIPTION –		DEPTH(ft)	275	PUBLIC WATER	Y / (N)
RESIDENCE	(Y) / N	PERSONS	4	BEDROOMS	3	TOTAL SQ.FT.	
COMMERCIAL	Y / (N)	PROPOSED USE–		N/A			
SYSTEM TYPE	TRENCH	(Y) / N	MOUND	Y / N	OTHER –	N/A	
LOW FLOW	TOILETS	(Y) / N	SHOWERS	(Y) / N	OTHER –	N/A	
SITE PLAN		Submit Site Development Plan According To Attached Instructions					

INFORMATION ABOVE IS TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE.

SIGNATURE John Doe Jr. — OWNER / APPLICANT — 9-1-90 DATE

FOR OFFICIAL DEPARTMENT USE ONLY. DO NOT WRITE BELOW THIS LINE.

FEE RECEIPT 00159		DATE	9–1–90	TOTAL PAID $	100
APPLICATION REVIEW					
SITE PLAN ATTACHED	(Y) / N	DATE	9–1–90	DATE COMPLETE	9–1–90
COUNTY W&S PLAN	(Y) / N	PROHIBITED ZONE		Y / (N)	
BAY CRITICAL AREA	Y / (N)	WHP AREA	Y / (N)	EXISTING RECORDS	(Y) / N
SOIL MAPPING UNITS	SaA, WoB,	Fg, Po		FLOODPLAIN SOILS	Y / (N)
WET SEASON TESTS	(Y) / N	GPR AREA	A	REVIEWED BY:	P.Servant
RECOMMENDATION	APPLICATION APPROVED		(Y) / N	DATE	9–2–90

FIGURE 3.1
Example application form.

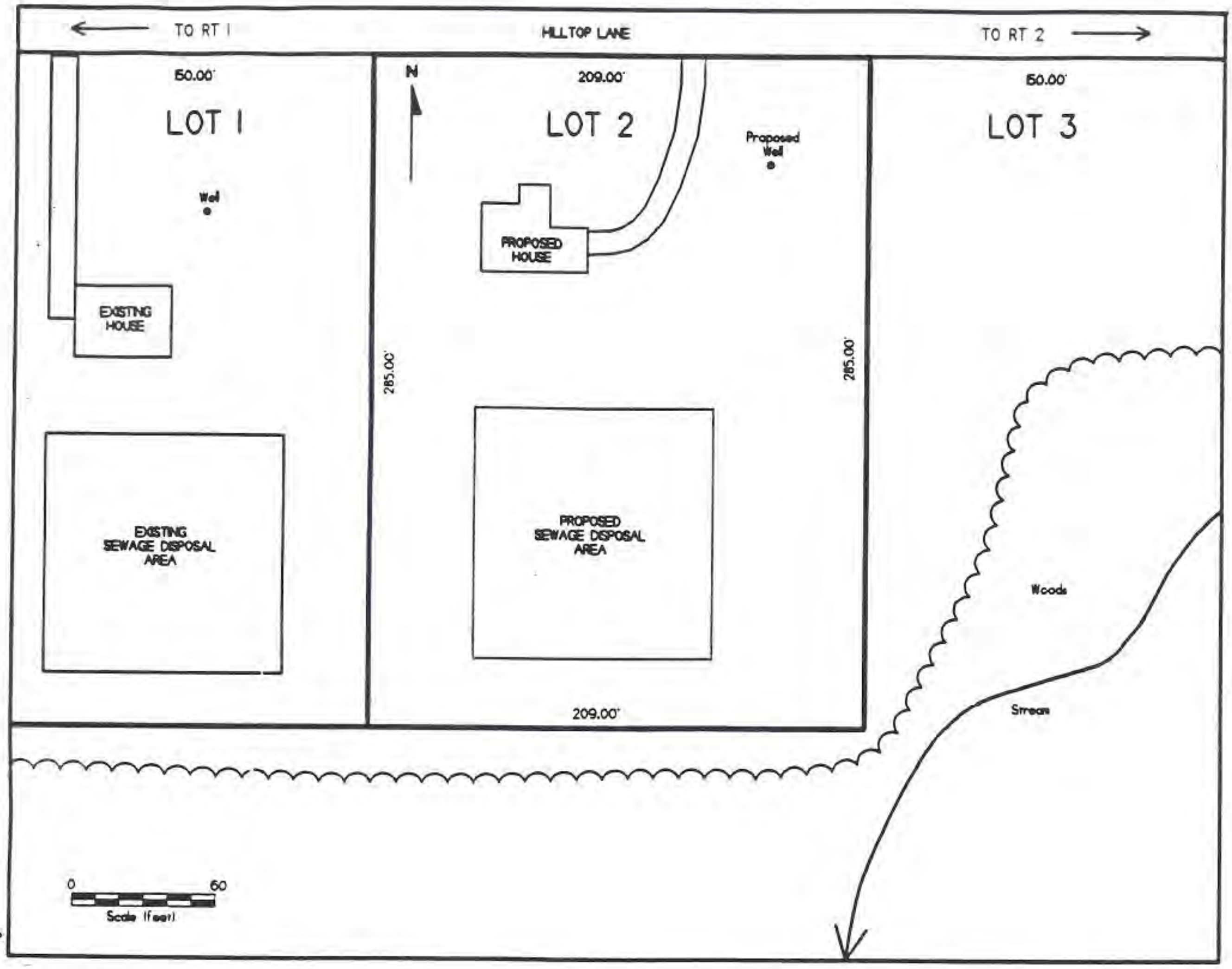


FIGURE 3.2
Example site plan.

- Proposed SDA is located on slopes in excess of 25 percent or on floodplain soils and flood-prone land areas as listed in the USDA–SCS soil survey.

3) Proposed SDA is located in a prohibited zone, as designated in a more stringent regulation or ordinance, such as a well head protection area (WHPA), resource protection zone (RPZ), or local groundwater protection report (GPR).

4) Proposed SDA, as shown on the site plan, does not meet horizontal setback distances; includes easements, utilities, right-of-ways, driveways or building sites; or does not have sufficient area as required by regulation.

5) Previous site evaluations and data indicate that the soil is not suitable or insufficient area of suitable soil is available within the property boundaries.

6) Local well records indicate that a safe and adequate water supply system cannot be obtained at the proposed site.

7) Existing records indicate the proposed SDA is located on areas of uncontrolled fill.

Rejection of an application based entirely on small scale site plans, soil survey maps and site sketches is not recommended. More accurate and detailed site plans or preliminary site visits by qualified professionals to measure slopes or provide soil classifications may be necessary.

4.0 STEP 2: PRELIMINARY EVALUATION

4.1 OBJECTIVES

This step in the process involves the collection and review of available resource information about the site and the surrounding area. The amount of time used to perform this step will depend on local approving authority staff workloads, available information and local experience. Although the information is general, it can be useful in identifying potential problems or particular features to investigate. The major objectives of this step are to:

1) collect and review available topographic, soil and hydrogeologic data;

2) examine local records of nearby site evaluations, soil tests, system designs and reported problems for on-site systems and wells;

3) identify potential problems or features to investigate during the detailed field investigation; and

4) conduct a preliminary screening and ranking of potential disposal system alternatives for the site based on all of the available data.

4.2 DATA COLLECTION AND REVIEW

4.2.1 Wastewater Characterization

Data from the application and from existing studies are used to estimate design flows and wastewater characteristics. Residential wastewater generating activities can be grouped into three use categories: (1) basins, sinks and appliances; (2) toilets; and (3) garbage disposals. The intermittent occurrence associated with these use categories and the variable quantities of pollutants associated with each use are responsible for large variations in flow and wastewater strength.

Existing data from EPA indicate average daily flow is approximately 45 gallons per capita per day (GPCD), with flows ranging from 8 to 102 GPCD (U.S. EPA, 1980). Based on available data, average daily flows seldom exceed 75 GPCD. Estimated residential design flows in Maryland regulations are based on a conservative 75 GPCD and the assumption of two people per bedroom (BR). Typically, the number of bedrooms given on the application form is multiplied by 150 GPD to estimate the design flow.

Example

3BR x 150 GPD/BR = 450 GPD

Available data showing selected chemical and biological characteristics of typical residential wastewater are presented in TABLE 4.1. A summary of the average contribution of selected pollutants from the three categories of residential wastewater-generating activities is presented in TABLE 4.2. Information for estimating maximum daily wastewater flow for nonresidential facilities is given in APPENDIX F.

4.2.2 Soil Survey Reports

4.2.2.1 Background

Soil surveys involve the systematic examination, description, classification and mapping of soils in an area. Soil surveys have been conducted, and reports published, for each county in the State. The surveys have been conducted under the National Cooperative Soil Survey Program by the USDA–SCS in cooperation with the Maryland Agricultural Experiment Station.

Th[illegible] contain maps showing the distribution of different soils across the landscape and information on soil properties and interpretations for potential farm and non-farm uses. Detailed soil maps are typically published on aerial photograph base maps. The maps are usually published at a scale of 1:15840 (1 in. = 1320 ft.) or 1:20000 (1 in. = 1660 ft.). An example soil map showing soil survey information is given in FIGURE 4.1, and a site plan with data transferred from a soil survey map is shown in FIGURE 4.2.

The [illegible]ions shown on the map are called mapping units. Each unit on the detailed map represents an area on the landscape and consists of one or more dominant soils for which the unit is named. Components of minor extent not identified in the map unit name are called inclusions (Soil Survey Staff, 1951; Soil Survey Staff, 1975; Soil Survey Staff, 1980; Soil Survey Staff, 1981). Inclusions in mapping units are due to limitations of map scale, complexity of soil patterns, depth of soil examined and experience of the field soil scientist. Many inclusions are too small to be delineated separately at the scale of mapping or cannot be accurately located using practical field methods. If differences are small, the inclusions can be described as similar. If differences are large, the inclusions can be described as dissimilar.

> **Similar Inclusions:** components occur together in the landscape and are alike in most properties. Interpretations for most common uses are alike or reasonably similar and the interpretative purity of the unit is not affected.
>
> **Dissimilar Inclusions:** components differ greatly in one or more properties and the differences affect major interpretations. Some dissimilar components are limiting and others are nonlimiting, depending on the interpretation being considered.

Inclusions may range from 15 to 50 percent of the soils in the mapping unit. Major soil components, whether dominant or inclusions, recognized during mapping and important to interpretations, are

TABLE 4.1

TYPICAL RESIDENTIAL WASTEWATER CHARACTERISTICS

PARAMETER	CONCENTRATION* (mg/l)
Total Solids	680–1000
Suspended Solids	200–290
BOD_5	200–290
COD	680–730
Total Nitrogen	35–100
Ammonia	6–18
Nitrate and Nitrites	18–29
Total Phosphorus	18–29
Phosphate	6–24
Total Coliforms (organisms/liter)	10^{10}–10^{12}
Fecal Coliforms (organisms/liter)	10^{8}–10^{10}

SOURCE: U.S. EPA (1980). Based on residences equipped with standard water-using fixtures and appliances (excluding garbage disposals) and flows of approximately 45 GPCD.

* Concentrations may be higher with requirement for 1.6 gal./flush toilets.

TABLE 4.2

SELECTED CHARACTERISTICS FROM MAJOR RESIDENTIAL WASTEWATER GENERATING ACTIVITIES

PARAMETER	BASIN, SINKS, APPLIANCES (mg/l)	TOILETS* (mg/l)	GARBAGE DISPOSAL (mg/l)	COMBINED WASTEWATER (mg/l)
BOD_5	260	280	2380	360
Suspended Solids	160	450	3500	400
Nitrogen	17	140	79	63
Phosphorus	26	20	13	23

SOURCE: U.S. EPA (1980). Based on the following wastewater flows: basins, sinks and appliances—29 GPCD; toilets—16 GPCD; and garbage disposals—2 GPCD.

* Concentrations may be higher with requirement for 1.6 gal./flush toilets.

SHEET NUMBER 16

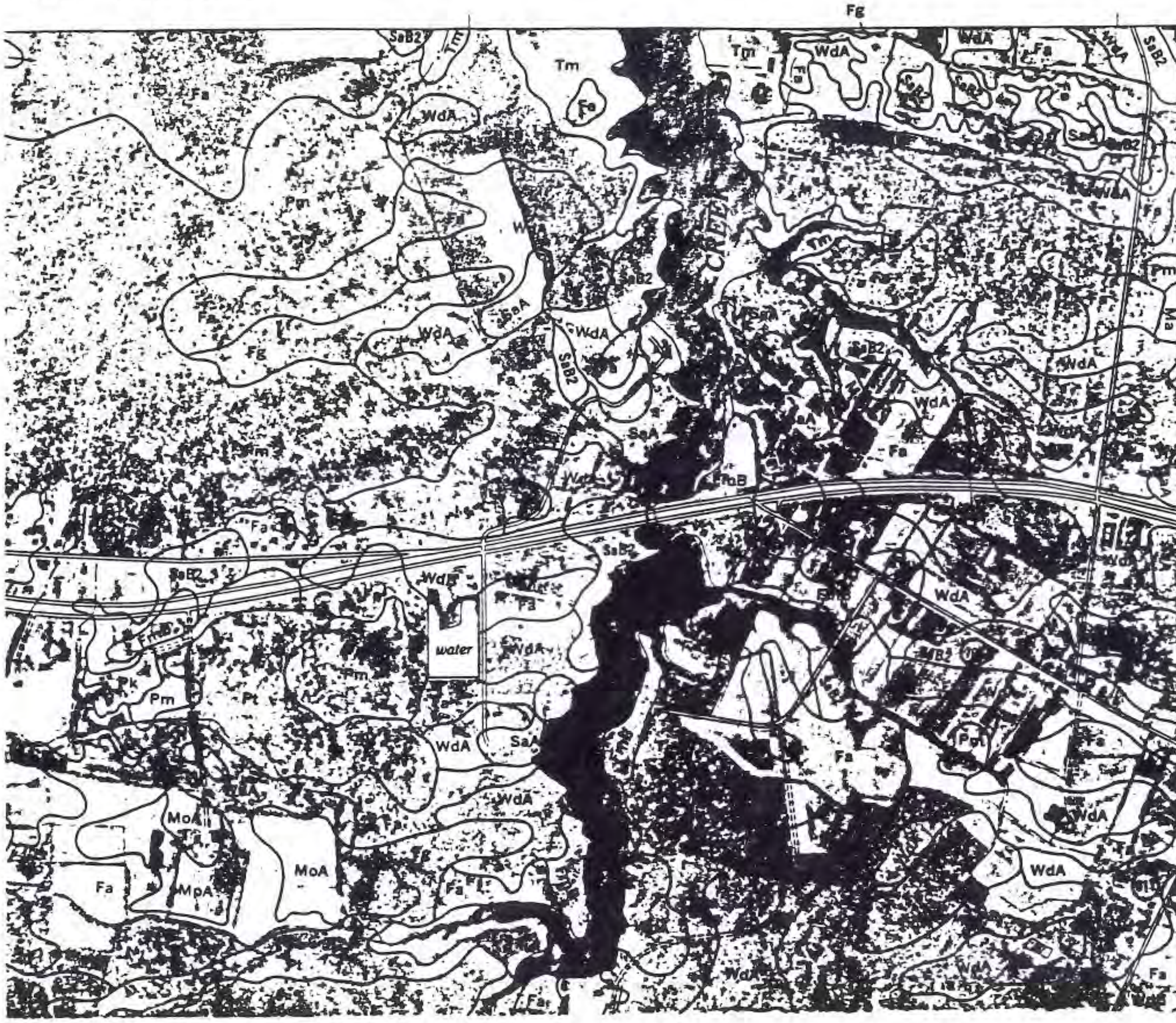


FIGURE 4.1

Example soil map taken from the Worcester County, Maryland soil survey report. Scale 1:15840 (1 in. = 1320 ft.).

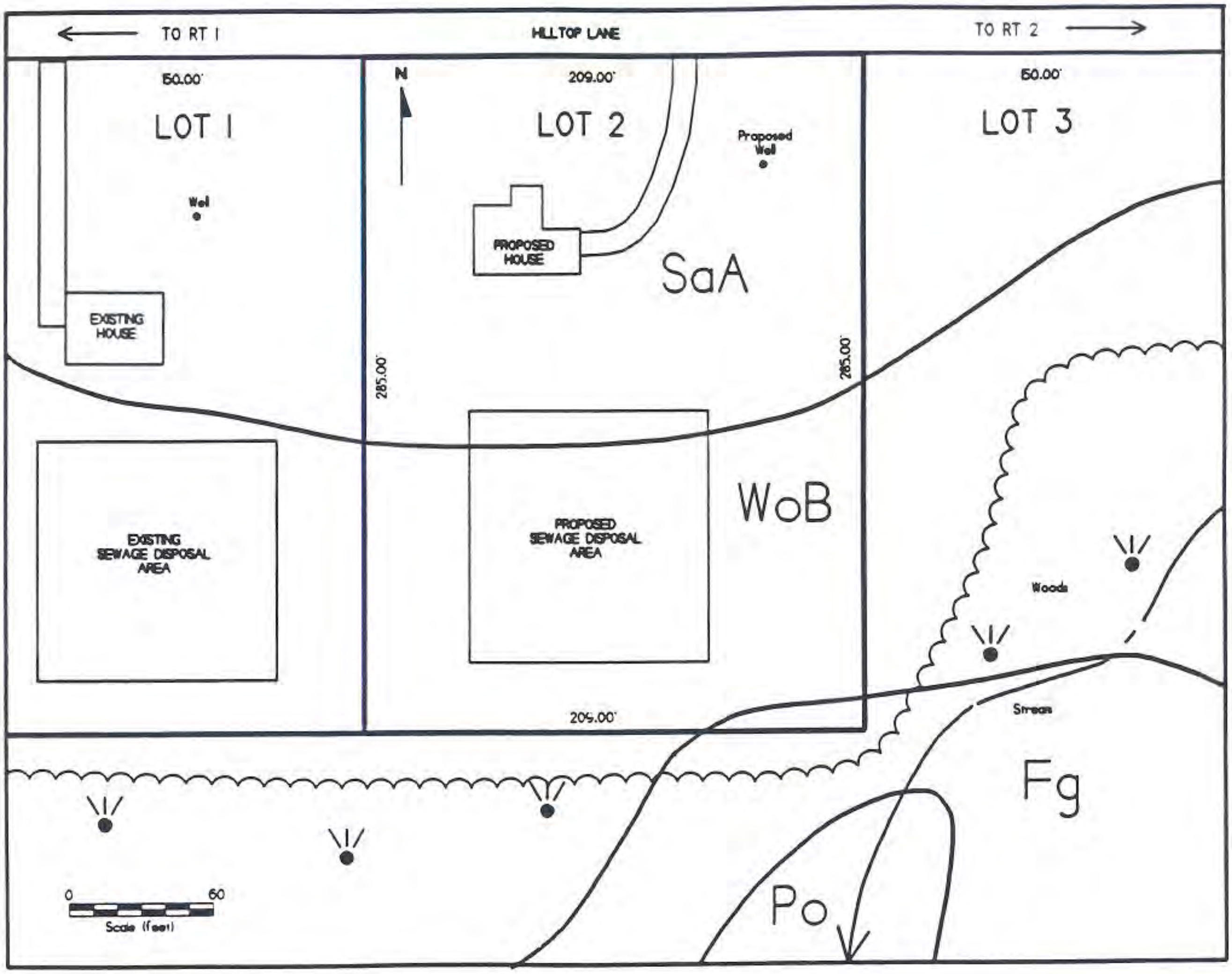


FIGURE 4.2

Example site plan showing soil mapping units and spot symbols transferred from a soil survey report.

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described in the report in the mapping unit descriptions section. FIGURE 4.3 illustrates an example of the relationship of soil map units and the potential location of similar and dissimilar inclusions in the mapping unit. The potential location of inclusions is best determined by soil scientists with mapping experience in the local area.

The mapping unit legend lists all of the mapping units and explains the map symbols. The map symbols give the name of the dominant soil or land type, the slope range and the degree of erosion.

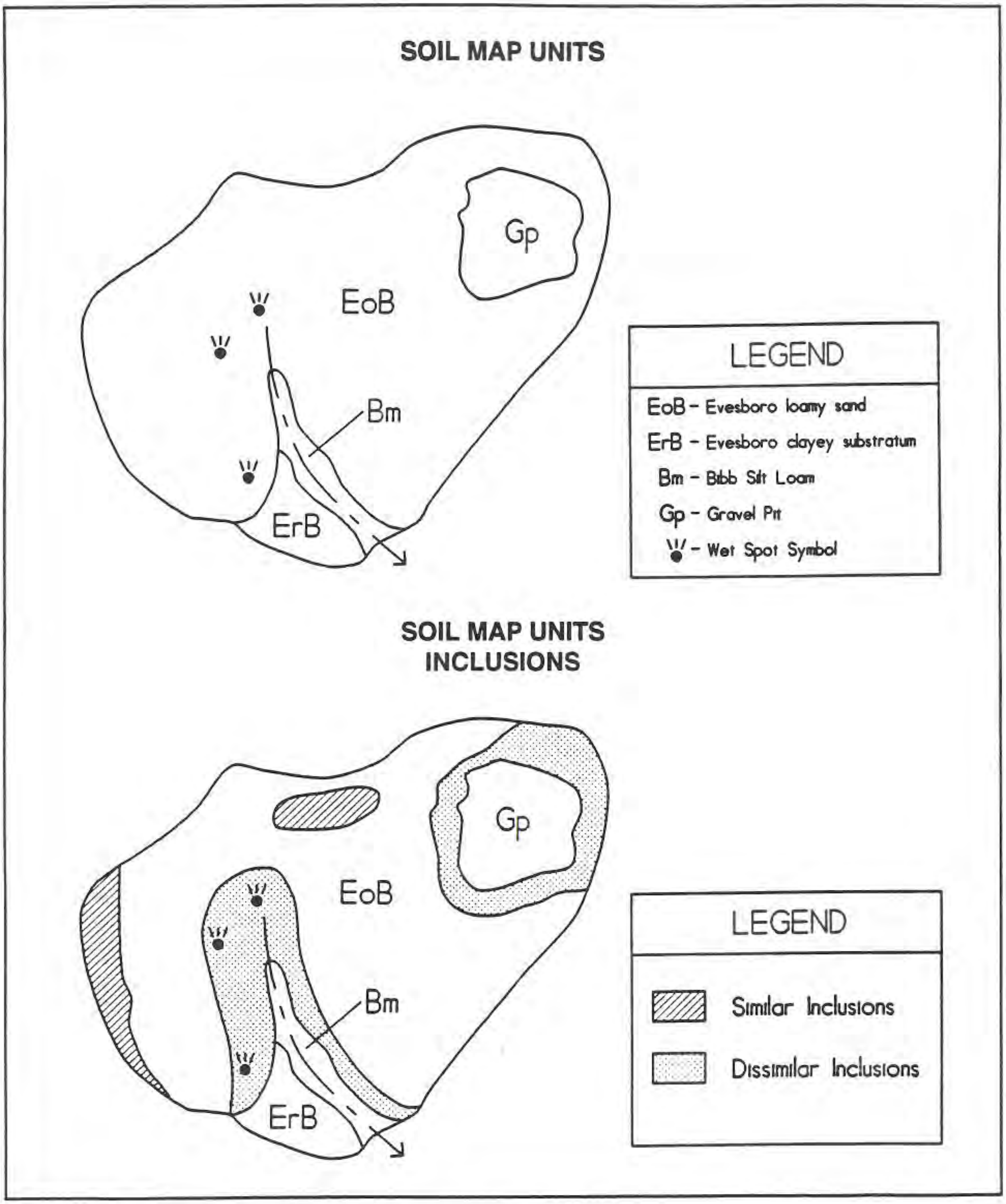


FIGURE 4.3

Relationship between soil mapping units and the potential location of similar and dissimilar inclusions.

The soil name is represented by a two letter symbol. The slope range is indicated by an upper case letter from A to F. The erosion class is indicated by a number that usually ranges from 1 to 3. Interpretations for potential uses and engineering properties are listed in tables within the text of the report. Users of this manual should check the appropriate soil survey to obtain an explanation of map symbols, slope range, erosion class and properties for each mapping unit of interest.

4.2.2.2 Procedure for Use

The following steps can be used to collect preliminary soil data for the site using the available USDA–SCS Soil Survey:

1) Locate the site or area of interest on the index to map sheets. Note the number of the map sheet and turn to that sheet in the survey.

2) Locate the site or area of interest on the map sheet and outline the site boundaries on the detailed soils map. Many counties have soil survey overlays for use with tax maps to facilitate locating soil mapping unit boundaries within specific property boundaries.

3) List the map unit symbols found within the site or area of interest. Use the index to map units to determine the name of each map unit and the page in the survey report where that map unit is described.

4) Review the description of each mapping unit, noting the dominant soil series and any inclusions that are typically found, and refer to the section that describes each soil series recognized. A range of characteristics typical for each soil series is found in the text descriptions.

5) Refer to tables in the report that describe engineering index properties, physical and chemical properties of the soils, and soil and water features and complete a summary list of soil properties as shown in TABLE 4.3.

6) Review the summary of soil data and recheck to determine if soils need to be tested during the wet season.

Users of this manual should take into consideration small scale limitations and other associated limitations of soil survey maps and should not rely solely on soil survey data to make decisions without field verification.

4.2.3 Topographic Maps

Site plans attached to the application may show adequate topographic data, depending on the amount of detail required by the local approving authority. Typically, the required site plans will show

TABLE 4.3

SUMMARY OF USDA SOIL SURVEY DATA FOR MAJOR SOIL UNITS MAPPED AT THE SITE

PROPERTY	MAPPING UNITS SaA	WoB	Fg	Po
Flooding Potential	None	None	None	None
Slope percent	0-2	2-5	0-2	0-2
Depth to Seasonal High Water (ft.)	>5	1.5-2.5	0	0
Depth to Rock or Pan (in.)	>60	>60	>60	>60
Solum				
Thickness (in.)	30-40	24-40	24-38	25-40
Texture Group(s)	3	3	3	3
Limiting Permeability (in./hr.)	0.6	0.6	0.6	0.6
Shrink–Swell Potential	Low	Low	Low	Low
Rock Fragment Content (percent vol.)	<15	<15	<15	<15
Substratum				
Depth (in.)	50	75	55	53
Texture Group(s)	2,3	2,3	2,3	2,3
Limiting Permeability (in./hr.)	2.0	2.0	2.0	2.0
Shrink–Swell Potential	Low	Low	Low	Low
Rock Fragment Content (percent vol.)	<15	<15	<15	<15

SOURCE: Hall, R.L. (1973). Sa–Sassafrass series, Wo–Woodstown series, Fg–Fallsington series, Po–Pocomoke series.

Soil Texture Groups: Group 1–gs, s, ls and coarser. Group 2–vfs, fs, lvfs, lfs, sl, l. Group 3–scl, sil, cl, sicl. Group 4–sc, sic, c.

topography within the property or in portions of the property and other features within 100 feet of the property boundary. This information can be supplemented by reviewing available topographic maps for the surrounding area. If the available topographic maps are not adequate for the particular site, th licant should be required to provide an adequate topographic survey.

Available maps can be used to estimate slopes and water table elevations, and to identify streams, springs, marshes, swamps, large depressions and sinkholes, regional drainage patterns, landforms, land use patterns and other cultural features surrounding the site. Quadrangle maps published by the U.S. Geological Survey (USGS) (7.5 minute series) are available for the entire State and are drawn to a scale of 1:24000 (1 in. = 2000 ft.). Because of their scale, however, these maps are of limited value for evaluating small parcels or lots. Larger scale topographic maps, at scales of 1:4800 (1 in. = 400 ft.) and 1:2400 (1 in. = 200 ft.), are available in some counties and should be used whenever possible.

4.2.4 Water Level Monitoring Network

Available data from nearby water table monitoring wells should be collected and analyzed to determine normal and extreme wet season fluctuations and whether the data may be generally representative of conditions in the vicinity of the proposed site.

Published water level monitoring data are available from the Maryland Geologic Survey (MGS) and the USGS (Smigaj and Davis, 1987; James and Smigaj, 1992). In addition, a number of local approving authorities have established shallow monitoring well networks on generally representative soil–landscapes. These networks are typically monitored each month throughout the year, more frequently from December into May, in order to advise applicants on the beginning and ending of wet season testing periods and to establish local records and patterns of normal and extreme water level fluctuations. An example well hydrograph is shown in FIGURE 4.4.

In the absence of any site-specific water level data, a judgement will need to be made to determine if the available data may be generally representative of the proposed site. Factors to consider when making a judgement are:

1) soil–landscape relationships and hydrogeologic data;

2) land surface elevations, local drainage density and local relief;

3) period of record and local precipitation during the record; and

4) methods of collecting the data and precision of the measurements.

4.2.5 Hydrogeologic Reports

Available data from published hydrogeologic reports, groundwater protection reports and well records should be collected and reviewed to determine the nature, properties, extent and water quality of aquifers underlying or in the vicinity of the site. Information and descriptions of geologic formations and hydrogeologic units can be used to determine the range of geologic materials that may be encountered at the site and the best methods for subsurface exploration.

4.2.6 Local Records

Records of previous site evaluations, reported system failures and water quality problems are a valuable source of information and should be reviewed for both the proposed site and the surrounding properties. Existing site evaluations on similar soil–landscapes may provide an indication of potential soil mapping unit inclusions, expected ranges of seasonal high water levels and percolation test results. A review of system failures may indicate performance problems related to soil properties or correlations between soil properties and percolation test results that can be helpful when making suitability recommendations. System types and site data, correlated with water

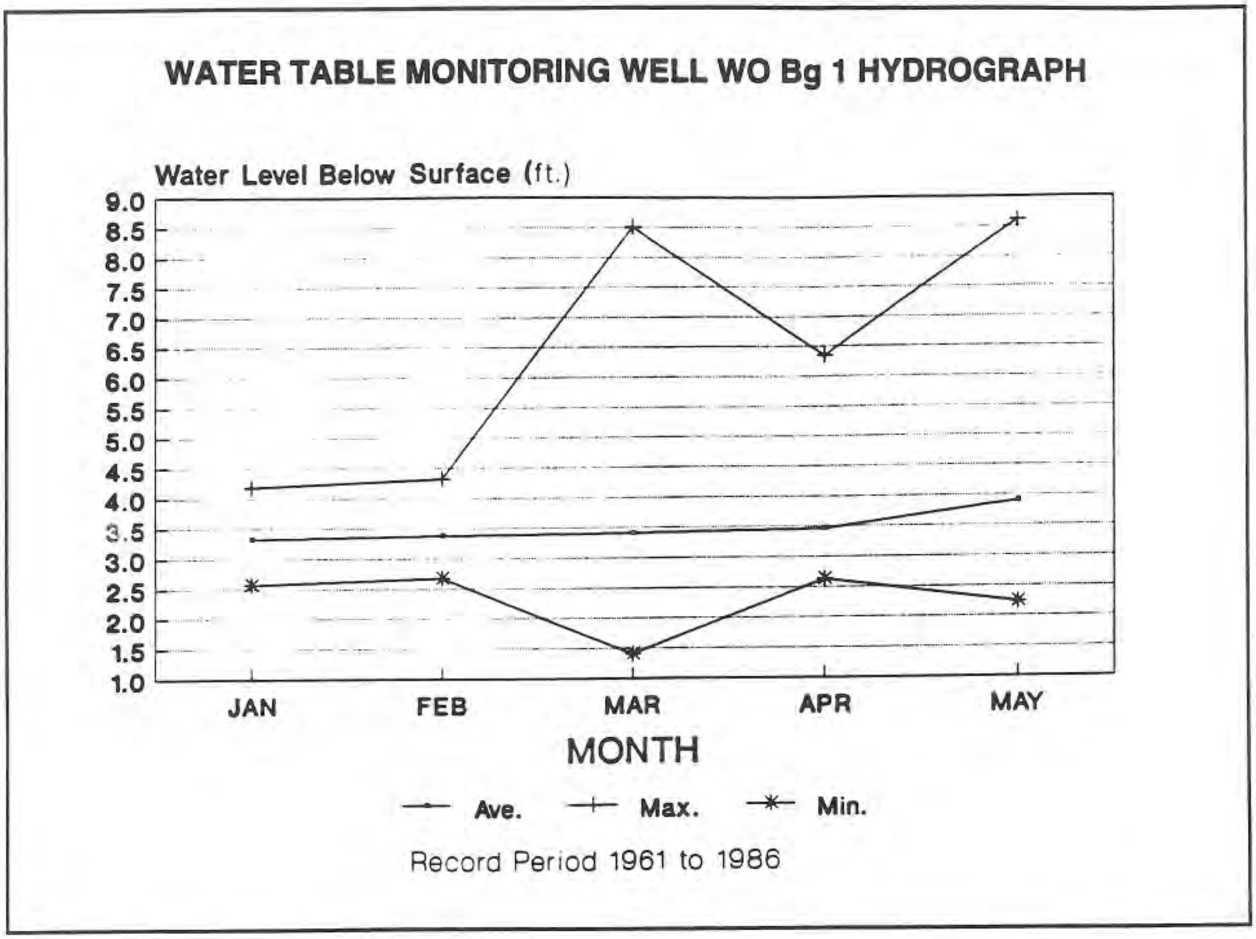


FIGURE 4.4

Example well hydrograph showing water table fluctuations.

quality problems, can be used to help assess existing site evaluation practices and the effectiveness of existing treatment zones and horizontal separation requirements.

4.3 POTENTIAL DISPOSAL SYSTEM ALTERNATIVES

Types of on-site disposal systems that are used in Maryland are listed and described in APPENDIX G. Approved systems include shallow and deep gravel-filled trench systems, sand mounds, and, in some areas, elevated beds, sand-lined trench systems and bermed infiltration ponds. Data on site criteria, design and construction for these systems are available in a number of references (U.S. EPA, 1980; MDE, 1987; MDE, 1991; MDE, 1992).

Soil survey data listed in TABLE 4.3 and data taken from available county groundwater protection reports can be used with various rating systems presented in APPENDIX H to determine the range of potential disposal system alternatives suitable for the site. For stratigraphic information beneath the soil profile, geologic logs should be reviewed. TABLES H.1 and H.2 in APPENDIX H present an example evaluation of potential alternatives for the SaA soil mapping unit using one rating system developed for systems used in Maryland.

The site screening criteria presented in APPENDIX H is very general and can be used only to provide a list of potential alternatives which may be feasible. Other rating or screening procedures that can be used to estimate the potential feasibility of on-site sewage disposal include the USDA–SCS rating system presented in each soil survey, and a more recent USDA–SCS procedure referred to as "Soil Potential Ratings," that is described in the *National Soils Handbook* (Soil Survey Staff, 1992a).

5.0 STEP 3: FIELD INVESTIGATION

5.1 OBJECTIVES

A detailed field investigation is necessary to confirm application and preliminary evaluation data and to determine site-specific soil suitability for on-site sewage disposal. Information collected during the investigation can be used to design or assist in the design of an on-site system if the site is acceptable. The main objectives of the field investigation are to:

1) Confirm information contained on the application form, attached site plan and the results of the preliminary evaluation.

2) Identify site features that may prohibit or limit the location of an SDA and conduct a landscape analysis to assess surface and subsurface water movement.

3) Select potential SDA(s) for examination and locations of subsurface excavations, and determine acceptability of locations with owner or applicant.

4) Examine the soils and the underlying geologic materials in each potential SDA(s) and make detailed soil–landscape descriptions at each excavation.

5) Identify any limiting zones in the soils and underlying geologic materials, and determine the minimum thickness of unsaturated suitable soil material available for treatment. Determine the need for treatment zone percolation tests.

6) Determine if the water table is a potential limiting zone and if piezometers will be required for water level monitoring. If required select the number, locations and depths of piezometers, and determine monitoring frequency.

7) Install piezometers if necessary and monitor water levels in the piezometers during the wet season.

8) Determine potential system type(s), and select the type(s), number(s), locations and depths of percolation and infiltration tests and any additional hydraulic conductivity tests.

9) Conduct or supervise percolation, infiltration and hydraulic conductivity tests, and record results of all tests performed.

10) Determine accurate locations of all excavations, tests and site features that may limit the location of the SDA, and estimate total usable area for the system.

5.2 SITE RECONNAISSANCE

A reconnaissance of the site and the surrounding area should be conducted before any subsurface excavations are made. Property lines and boundary stakes should be located, and the site and surrounding properties within 100 feet should be checked for any identifiable surface conditions and sources of contamination that may limit the location and testing for on-site sewage disposal. Limiting conditions, if detected, should be located accurately on the site plan and noted in the field notes.

In addition to identifying and locating any limiting surface conditions, landscape features that may affect surface water drainage, runoff, soil moisture, flooding and potential erosion should be noted and described.

5.2.1 Identification of Limiting Surface Conditions

Surface features that may limit the location of an SDA and other system components include, but are not limited to, the following:

- water well systems completed in confined aquifers within 50 feet;
- water well systems completed in unconfined aquifers within 100 feet or located downslope of a proposed SDA;
- steep slopes (i.e., >25%) within 25 feet;
- seeps, springs, drainageways and gullies within 25 feet;
- flood plain soils within 25 feet;
- rock outcrops within 25 feet;
- sinkholes, streams and surface water bodies within 100 feet; and
- streams tributary to water supply reservoirs within 200 to 300 feet.

5.2.2 Landscape Analysis

A landscape analysis should be conducted in the SDA(s) and surrounding vicinity as part of the site reconnaissance. The analysis is used to assess the potential effects of landscape features on the movement of surface and shallow subsurface water. Landscape features such as slope length, width, position and gradient can be used with other soil profile properties to select SDA(s) and help predict water movement in the landscape. A number of conceptual models have been proposed to describe

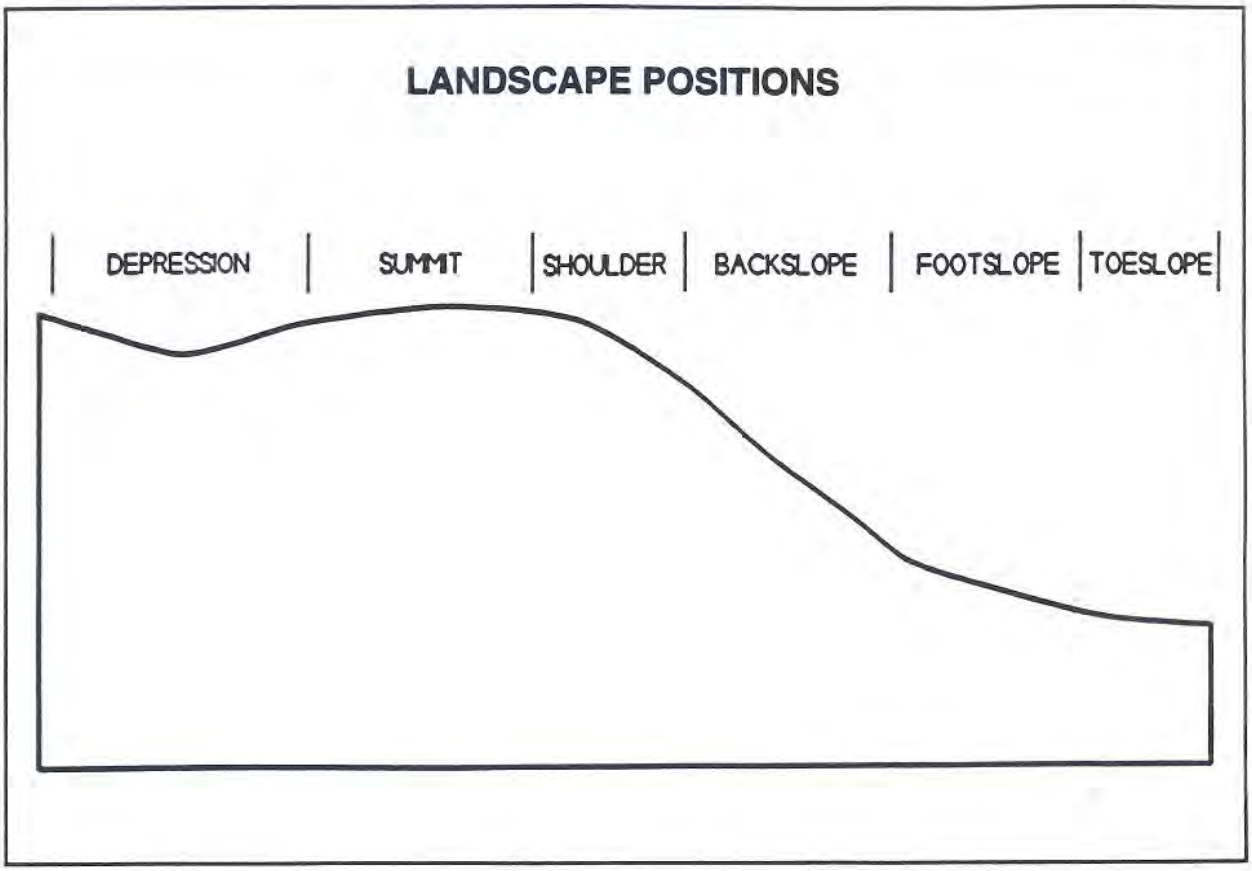
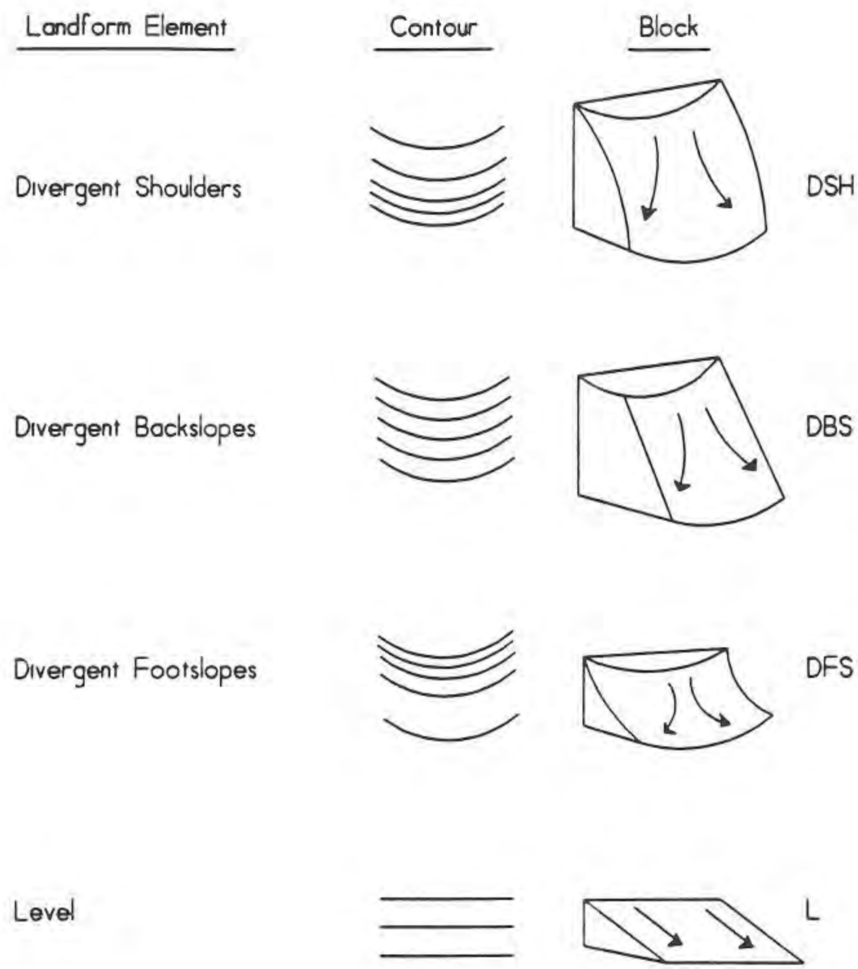


FIGURE 5.1
Landscape positions.

landscape features and hillslopes (Ruhe, 1975; Pennock et al., 1987; Fanning and Fanning, 1989; Hall and Olson, 1991; Daniels and Hammer, 1992; Moore et al., 1993). The model proposed for use in this manual is modified after Ruhe (1975) and Pennock et al. (1987). Position generally refers to the point on the landscape where the soil is located. Positions as described below and in FIGURE 5.1 imply certain shapes along the length of the slope, perpendicular to the contours (i.e., profile curvature). The basic shapes are convex, linear and concave. Across the landscape or landform, roughly parallel to the contours, these same terms can be used to describe the shape of the slope width (i.e., plan curvature). Convergent and divergent elements, as illustrated in FIGURES 5.2 and 5.3, can be used to identify landscape features that tend to concentrate surface and subsurface drainage into proposed SDAs. The following sections provide a general description of the landscape positions depicted in FIGURE 5.1:

> **Summit:** upland areas along divides between watersheds. May be gently sloping to nearly level. Depending on soil infiltration rates, types of horizons, permeability and vegetative cover, water that infiltrates moves principally downward under unsaturated conditions.

HILLSIDE ELEMENTS



(Pennock et al., 1987)

FIGURE 5.2
Divergent hillside elements and landscape positions.

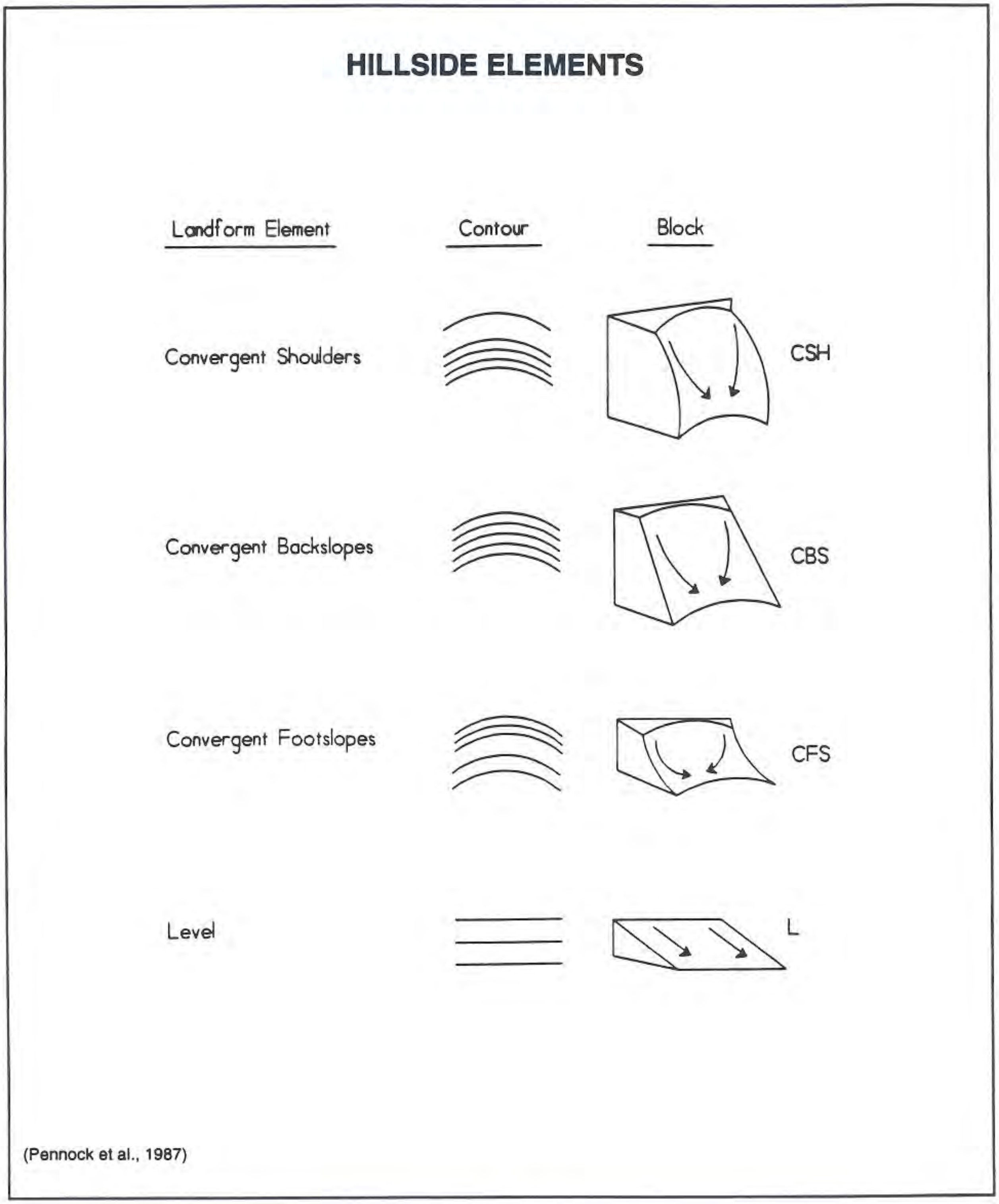


FIGURE 5.3
Convergent hillside elements and landscape positions.

Shoulder: top of slope; convex in length sloping towards drainageways. May have convex, concave or linear shape along slope width. If concave along width, runoff tends to converge and may form defined channel flow. If linear, runoff tends to remain as sheet flow and is relatively uniform over the landscape.

Backslope: farther down slope; linear in length sloping towards breaks in slope (referred to as benches), footslopes and drainageways. May have convex, concave or linear shape along width with same runoff relationships as described above.

Footslope: base of slopes; concave in length sloping gently towards bench shoulders or toeslopes. May have convex, concave or linear shape along width. Fragipans are commonly found in these positions in the Appalachian Province. Interceptor drainage may be needed on lower one-third of slopes to divert lateral water flow from on-site systems.

Toeslope: nearly level to level areas in broader drainageways. Commonly adjacent to defined channels and composed of older or recent material deposited by streams. If surface elevations are above active floodplains and soils show general ABC horizon development, record as terrace toeslope. If on active flooding areas with AC horizon development, then record as floodplain toeslope.

Depression: closed basins with no external drainage. These include sinkholes and Maryland basins (e.g., "whale wallows").

The cited references and APPENDIX A should be consulted for additional explanations and detailed information.

5.2.3 Selection of Potential Sewage Disposal Areas

Based on the data collected during the site reconnaissance, potential SDA(s) can be selected for subsurface investigation(s). More than one potential SDA may be identified, and whenever possible the best area should be selected. In many cases the SDA will be given a tentative location by the owner or may be limited to the only potentially available area. If the owner/applicant is present during the site reconnaissance and it is determined that a better SDA is available, a recommendation to relocate the SDA should be made. If the new location is acceptable to the owner/applicant, then subsurface investigations should be conducted at the new location, and field notes and associated site plans should record the new location.

5.3 SOIL PROFILE DESCRIPTIONS

5.3.1 Background

The preparation of detailed soil profile descriptions during the field investigation is an integral part of the site evaluation process. Soil profile descriptions at a minimum should include the following:

- changes in horizons, specifying boundary depths;

- texture and rock fragment content;

- color and color patterns;

- moisture;

- mottling, degree and extent and other redoximorphic features; and

- additional notes on caving, depth to groundwater and consolidated bedrock.

To make estimates of saturated hydraulic conductivity and to determine if horizons or layers are limiting zones to water movement, the following additional properties should be described:

- structure, grade and type;

- consistence; and

- soil or ped surface features such as manganese coatings and clay skins, and soil pores.

5.3.2 Methods

Soil descriptions and evaluation of substratum conditions can be made most accurately from test pits dug by a backhoe or other excavating equipment. Utilizing a backhoe generally makes the best use of time during field investigations and is highly recommended in areas with deep water tables and soils with a high rock fragment content.

Hand augers generally are used in areas with high water tables and in unconsolidated soils with low rock fragment content. In general, detailed and accurate soil descriptions are more difficult to make from auger holes, and soil properties such as structure, pores and surface coatings cannot be evaluated properly. Hand auger examinations, in most instances, should be supplemented with backhoe test pits. It may be possible to supplement hand auger holes by checking soils exposed in nearby road cuts, railroad embankments, stream banks, surface drainage ditches or exposed slopes.

5.3.2.1 Depth

When utilizing backhoe test pits, it is extremely important that safety precautions and applicable OSHA and MOSH regulations be observed at all times. Excavations should be initially dug to depths of approximately 4 feet below land surface and oriented so that the sun can shine on a sidewall face during the examination. After initial descriptions are made, the pit should be extended in length and deepened at one end. Deep test pits should not be entered. Soil and geologic materials from each major horizon or layer encountered should be described, and depths of each horizon or layer measured from land surface. Soil materials suitable for wastewater disposal should be noted, and the excavation depth should extend a minimum of 4 feet below the lowest elevation of the potential bottom infiltrative surface (i.e., minimum depth below land surface of 5 to 7 feet).

The total depth of each excavation will be determined by soil conditions and the presence or absence of limiting zones or the limitations of the excavating equipment. In some areas of the State, local policies limit the maximum depth of deep trench systems or seepage pits and thus determine the total depth of excavations needed to properly evaluate the soils.

5.3.2.2 Number and Locations

A minimum of three excavations should be made for each proposed SDA with relatively uniform soil (i.e., same soil series). If several areas are being examined on one lot or several adjacent lots are being examined and soils are relatively uniform, then a minimum of one excavation per SDA may be acceptable. However, if more than one soil series is mapped in the proposed SDA, or if landscape, surface or subsurface features suggest different soils, then additional excavations may be necessary to determine soil variability and to select representative percolation test locations and depths.

5.3.3 Equipment

Proper equipment for making soil profile descriptions includes the following items:

- soil profile description forms;
- Munsell color book;
- trowel or knife;
- spade or shovel;
- bucket auger with extensions;
- water bottle with mister or sprayer;
- clinometer, abney level or hand level;
- tape measures (100 ft., 25 ft., 6 ft.);
- hand lens (10x magnification);
- mirror;

- flagging and/or stakes for marking holes; and

- appropriate clothing.

Additional equipment that may prove useful includes: camera, soil sample bags, field guides for estimating soil properties, geologist's hammer, and level with tripod and rod.

5.3.4 Procedures

The following general procedures are recommended for describing soil–landscape properties and making detailed soil profile descriptions during the field investigation. FIGURE 5.4 provides an example of a completed soil profile description form, and a blank form is given in APPENDIX D. The users of this manual should refer to available publications of the USDA–SCS (Soil Survey Staff, 1951; Soil Survey Staff, 1975; Soil Survey Staff, 1980; Soil Survey Staff, 1981; Soil Survey Staff, 1992a; Soil Survey Staff, 1992b) and APPENDIX A for additional information and detailed explanations.

5.3.4.1 Landscape Position and Slope

For each soil profile description, landscape position and percent slope should be noted and recorded on appropriate forms. Slope percent should be estimated using a clinometer, abney level or hand level. The landscape positions described previously, and illustrated in FIGURES 5.1, 5.2 and 5.3, should be used whenever possible. If slopes are complex or change dramatically throughout the proposed sewage disposal area, it may be necessary to measure slope along a number of transects or require that a detailed contour map of the sewage disposal area be constructed by a registered surveyor. Slopes greater than 25 percent cannot be used for on-site sewage disposal systems.

5.3.4.2 Horizons and Layers

A soil profile is composed of a series of horizons or layers that differ from each other in one or more properties such as texture, content of rock fragments, color, structure and consistence. The topsoil and subsoil, referred to as the solum, have been affected most by soil forming factors. The solum grades into substratum geologic materials. These materials may be stratified sediments, loess, colluvium, recent alluvium or residuum (saprolite) formed from weathering of bedrock.

Recognition of major horizons can help predict how water will move in the soil. Decisions as to what horizon name to use are not as important as actually locating and measuring depths of potential restrictive horizons or substratum layers (e.g., B-horizons of maximum clay accumulation, fragipans, dense substratum layers, ironstone, bedrock).

The following master horizons are expressed to varying degrees in undisturbed soils and should be looked for:

MARYLAND DEPT. OF THE ENVIRONMENT ONSITE SEWAGE DISPOSAL PERMIT SITE EVALUATION REPORT	
SOIL PROFILE DESCRIPTION	FILE NO. WO-200-SE-90
	MD. GRID: N180/E1340
	COUNTY: WORCESTER
	TAX MAP/B/P: 103/B/65
	SUBDIVISION: HILLTOP
LOT 2 SECTION 1	DATE: 4-12-91

DEPTH (in.)		TEXTURE	MATRIX COLOR	MOTTLES DESCRIPTION		STRUCTURE	CONSISTENCE	REMARKS (R.F.%,Moisture)
HOLE TP 2B							BY: P.Servant	
0	8	L	10YR 4/3			1-2mg	fr	moist
8	23	SCL-L	7.5YR 5/6			2m-cosbk	fr	moist
23	33	SL	10YR 5/6	c2d	10YR 6/2	2msbk	fr	moist
				c2d	7.5YR 5/6			
33	48	SIL-L	2.5Y 6/2			massive	fr	v.moist-wet
48	90	SR	2.5Y 6/2	f1d	2.5Y 5/6	massive	fi-fr	wet
		GSL-LS						
Slope%	2	EL.(ft)-		Chroma 2-	32in.	Least Permeable Layers-		8-23 in.
Landscape Position-			DBS	Water BLS-	48in.	Limiting Zones-		33-48 in.
Additional Remarks-								
HOLE TP 2C							BY: P.Servant	
0	8	L	10YR4/3			1-2mg	vfr	moist
8	16	L	10YR4/6			2msbk	fr	moist,plowpan
16	21	SL	10YR4/6			1-2mpr	fr	moist
21	36	SR SL-LS	10YR 5/6	m3d	7.5YR 5/6	massive	fr	moist
36	65	SIL-SICL	2.5Y 6/2	c2d	2.5Y 5/6	massive	fi	v.moist-wet
65	90	COSL	2.5Y 6/2			massive	fi	wet
Slope%	2	EL.(ft)-		Chroma 2-	36 in.	Least Permeable Layers-		8-16 in.
Landscape Position-			DBS	Water BLS-	36 in.	Limiting Zones-		36-90 in.
Additional Remarks-								

FIGURE 5.4

Example soil profile description form.

O: layer dominated by organic matter, leaf litter, twigs, etc.

A: mineral horizon formed at the surface or below an O-horizon and characterized by the accumulation of humified organic matter mixed with mineral particles. Considered topsoil.

E: mineral horizon in which main feature is loss of clay, organic matter, iron and aluminum oxides. This horizon is generally lighter in color than the A- or underlying B-horizon. Considered topsoil.

B: mineral horizon generally characterized by a zone of accumulation of clay, iron oxides and sometimes organic matter. These materials usually were leached from the A- and E-horizons.

C: mineral horizons, excluding hard bedrock, that are little affected by soil-forming factors, but often weathered to some degree. This horizon includes stratified sediments and both massive and structured saprolite.

R: relatively consolidated bedrock that cannot be dug with a spade.

FIGURES 5.5 and 5.6 illustrate the relationships of master horizons and potential subdivisions of the master horizons.

5.3.4.3 Soil Texture

Texture is the relative proportion and distribution in soil of various sizes of individual solid particles that are less than or equal to 2mm in diameter. The solid particles are divided into three size groups called separates and referred to as sand, silt and clay size particles. A number of different classification systems with different size limits have been devised. The classification system used in this manual is the USDA system. The size limit ranges of the USDA system are given in TABLE 5.1.

Twelve textural classes are used in the USDA textural classification system. The classes are defined by the relative proportion of sand, silt and clay separates. FIGURE 5.7 shows the twelve classes and is referred to as the USDA *textural triangle*. The texture of a sample of soil can be determined by measuring or estimating the percent by weight of each soil separate and then referring to the triangle for the appropriate class name.

Example: A sample with 70% sand, 12% silt and 18% clay falls within the textural class known as sandy loam.

Estimating soil texture in the field is done by the feel of moist soil when worked in the hands and rubbed between the thumb and fingers. Moisten a sample of soil about one-inch in diameter. The sample should be worked until it has a consistency like putty. Press and squeeze the sample in the

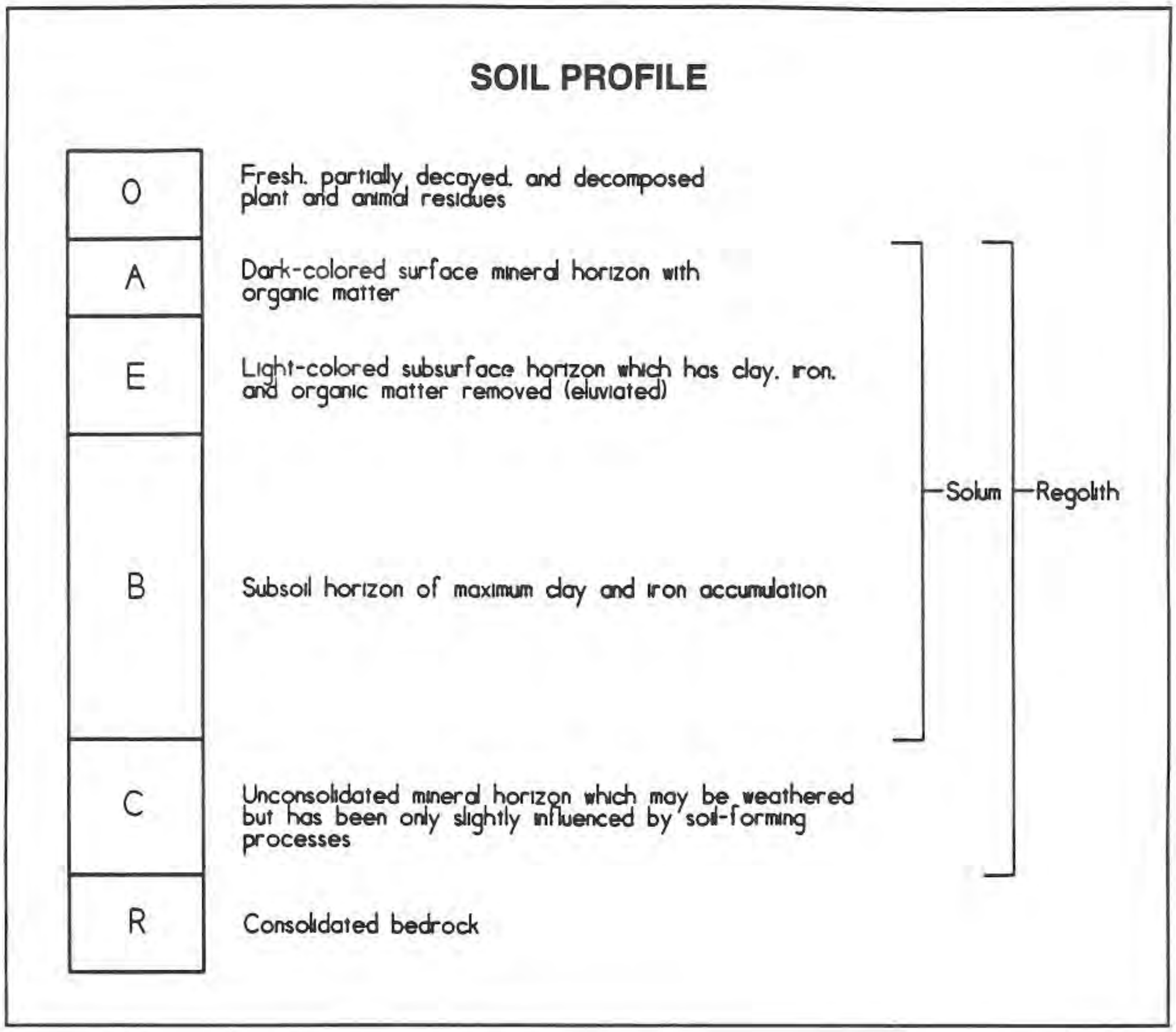


FIGURE 5.5

Generalized soil profile showing master horizons.

palm, and then force part of the sample between thumb and forefinger to try to form a ribbon. TABLES 5.2 and 5.3 can assist in estimating field textures. Standard abbreviations for textural classes and modifiers are provided in APPENDIX D. Routine practice with samples that have undergone laboratory analysis is the best method to learn and continually "calibrate" field estimating techniques.

Soil texture should be described and recorded for each major soil horizon or layer. If the soil sample appears to be on the boundary between two textural classes, record both classes with your best

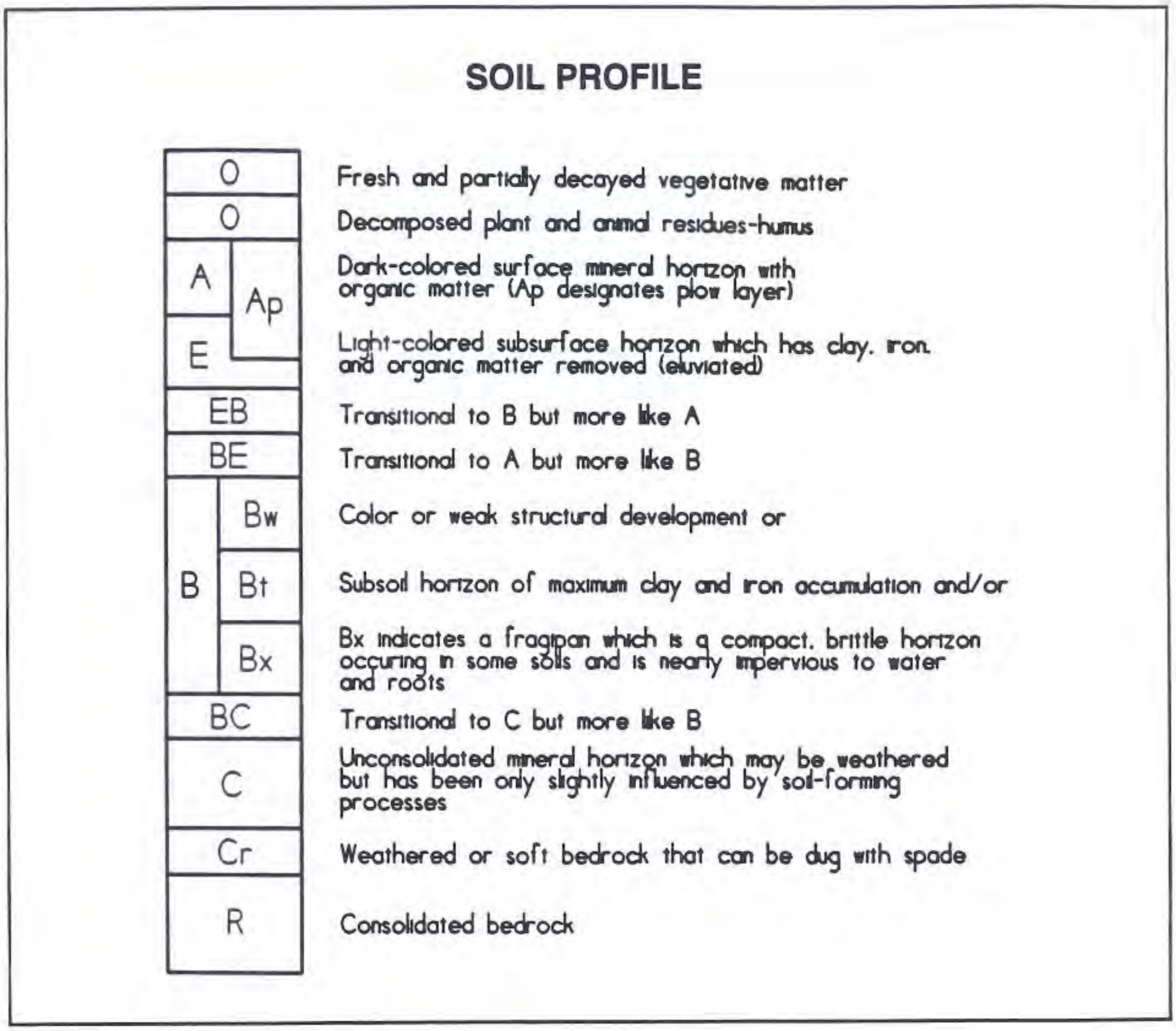


FIGURE 5.6

Generalized soil profile and potential subdivisions of the master horizons.

estimate first. Alternatively, estimate and record the percent of sand, silt and clay for each horizon or layer.

Soil texture estimates are important because texture affects water and gas movement through soil pores. Pore size, pore size distribution and pore continuity are all influenced by soil texture. In addition, soil texture can be a general indicator of the ability of soil to filter, retain or adsorb pollutants from applied wastewater. For example, coarse-textured soils such as sands and loamy sands generally have large continuous pores that can accept and transmit large amounts of water. The capacity of coarse-textured soils to retain water and filter or adsorb chemicals is generally low.

Fine-textured soils such as clay, silty clays and sandy clays do not transmit or drain water rapidly, due to small pore sizes. However, the capacity of fine-textured soils to filter and adsorb chemicals is generally high.

5.3.4.4 Rock Fragment Contents

Rock fragments are unattached pieces of rock greater than 2mm in diameter. Rock fragments influence moisture storage, infiltration, permeability and chemically reactive surfaces for wastewater renovation. Rock fragments are described in terms of their amount by volume, size and shape. Soil textural classes are modified if rock fragments exceed 15 percent by volume of the soil. TABLE 5.4 presents rock fragment names and size ranges typically found in soils. TABLE 5.5 presents the volume estimate percentages and the adjective form of a class name used as a modifier of the soil texture class. FIGURES 5.8 and 5.9 provide charts that can be used to estimate volume percent for rock fragments and other features (see APPENDIX D for standard abbreviations).

Rock fragment contents are important in determining the suitability of material in the required soil treatment zone. When rock fragment contents exceed 50 percent by volume, the approving authority may consider the soil treatment zone inadequate.

5.3.4.5 Soil Color and Color Patterns

Soil color and patterns can be used generally to infer relative organic matter content, soil wetness conditions and drainage related characteristics. Some soil colors are inherited from the parent material and may not reflect drainage or wetness conditions. Soil colors can be measured and described by comparison to a standardized Munsell color chart (Soil Survey Staff, 1951; Munsell,

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TABLE 5.1

USDA SIZE LIMITS FOR SOIL SEPARATES

SOIL SEPARATE	SIZE RANGE (mm)
Sand	2.0–0.05
Very coarse	2.0–1.0
Coarse	1.0–0.5
Medium	0.5–0.25
Fine	0.25–0.10
Very fine	0.10–0.05
Silt	0.05–0.002
Clay	<0.002

SOURCE: Soil Survey Staff (1992a).

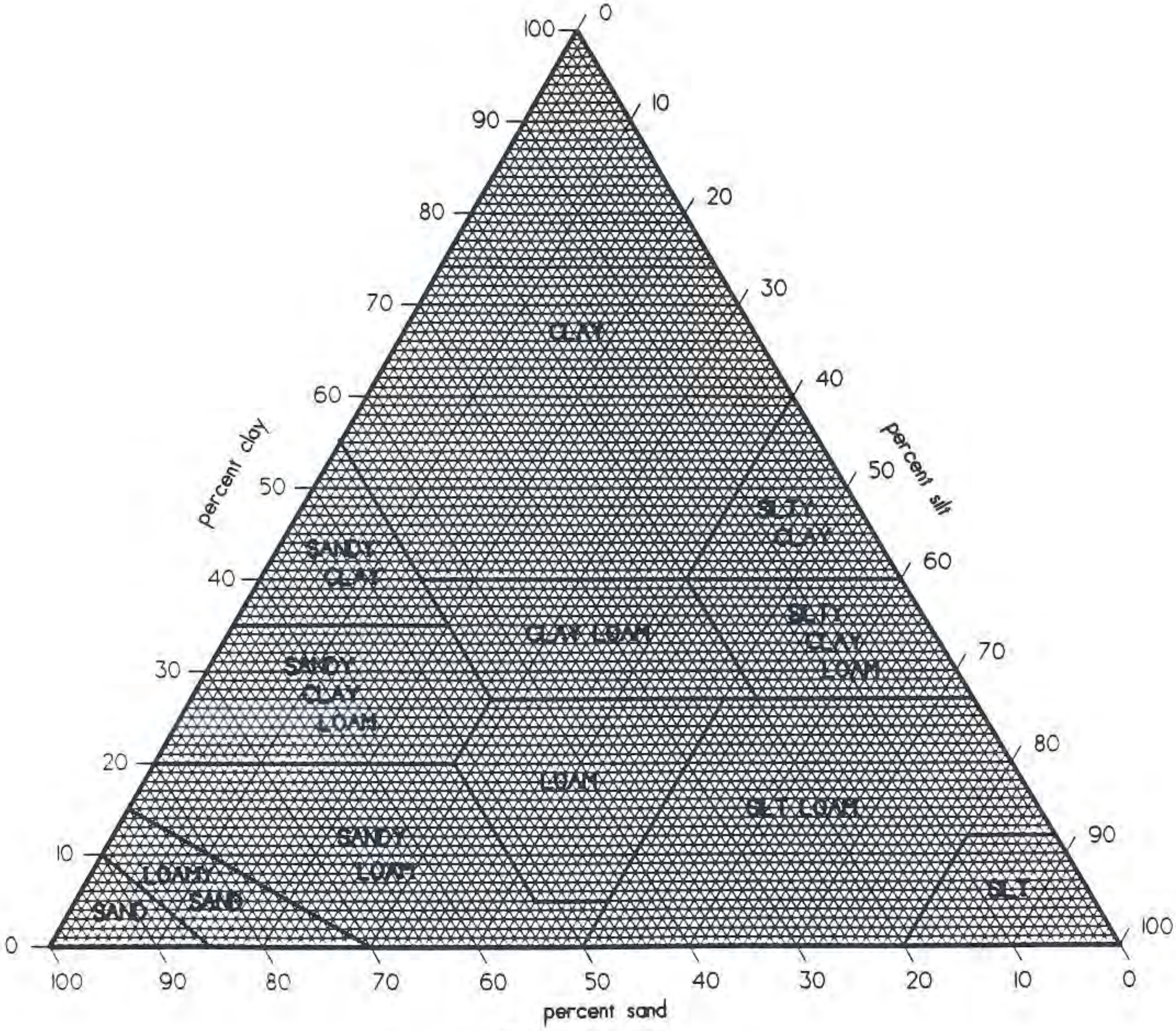

FIGURE 5.7

USDA–SCS soil textural classes.

1975; Soil Survey Staff, 1981). Colors in the Munsell system are described in terms of hue, value and chroma.

The hue notation of a color indicates the quality of color registered by the eye as related to the wave length. The Munsell system is based on the spectral colors of red(R), yellow(Y), green(G), blue(B) and purple(P). Value indicates relative lightness or darkness in relation to a neutral gray and ranges from black to white. Chroma indicates the departure of a given hue from a neutral gray color of the same brightness or value.

TABLE 5.2

FIELD CRITERIA USED TO ESTIMATE MAJOR USDA TEXTURAL CLASS

TEXTURAL CLASS	FEEL (MOIST)	FORM STABLE BALL	RIBBON OUT & STAIN HANDS	PLASTIC PROPERTIES	STICKY	MOIST CONSISTENCE
Sand	Very gritty	No	No	No	No	Loose
Loamy sand	Very gritty	No	No (slight staining)	No	No	Loose
Sandy loam	Gritty	Yes	Yes (dull surface; poorly formed)	No	No	Very friable
Loam	Gritty	Yes	Yes (dull surface; poorly formed)	Yes (slight)	Yes (slight to moderate)	Friable
Silt loam	Velvety	Yes	Yes (dull surface; poorly formed)	Yes (slight to moderate)	Yes (slight to moderate)	Friable
Silty clay loam	Velvety & sticky	Yes (very stable)	Yes (shiny surface; well formed)	Yes (moderate)	Yes	Friable to firm
Clay loam	Gritty & sticky	Yes (very stable)	Yes (shiny surface; well formed)	Yes (moderate)	Yes	Firm
Sandy clay loam	Very gritty & sticky	Yes (very stable)	Yes (shiny surface; well formed)	Yes (moderate)	Yes	Friable to firm
Silty clay	Extra sticky & very smooth	Yes (very resistant to molding)	Yes (very shiny surface; well formed)	Yes (strong)	Yes (very sticky)	Firm to extra firm
Clay	Extra sticky with slight grittiness	Yes (very resistant to molding)	Yes (very shiny surface; well formed)	Yes (strong)	Yes (very sticky)	Firm to extra firm

SOURCE: Modified from Foss et al. (1975).

TABLE 5.3

FIELD GUIDE FOR ESTIMATING USDA SOIL TEXTURE CLASS

TEXTURAL CLASS	ABBREVIATION	DESCRIPTION
Sand	s	Gritty feel, does not stain the fingers and does not form a ball when moist.
Loamy sand	ls	Gritty feel, stains the fingers (silt and clay) and forms a weak ball but cannot be handled without breaking.
Sandy loam	sl	Gritty feel, forms a ball that can be picked up with the fingers and handled with care without breaking.
Loam	l	Slight gritty feel but does not show a finger print and forms only short ribbons of from 0.25 inch to 0.50 inch in length. Will form a ball that can be handled without breaking.
Silt loam	sil	Floury feel when moist and will show a finger print but will not ribbon and forms only a weak ball.
Silt	si	Floury feel when moist and sticky when wet but will not ribbon. Forms a ball that will tolerate some handling.
Sandy clay loam	scl	Gritty feel but contains enough clay to form a firm ball. May ribbon to form 0.75 inch to 1 inch long pieces.
Silty clay loam	sicl	Sticky when moist and will ribbon from 1 to 2 inches. Rubbing silty clay loam with the thumb nail produces a moderate sheen. Produces a distinct finger print.
Clay loam	cl	Sticky when moist. Forms a thin ribbon of 1 to 2 inches in length and produces a slight sheen when rubbed with the thumb nail. Produces a non-distinct finger print.
Sandy clay	sc	Plastic, gritty and sticky when moist. Forms a firm ball and produces a thin ribbon to over 2 inches in length.
Silty clay	sic	Plastic and sticky when moist and lacks any gritty feeling. Forms a firm ball and readily ribbons to over 2 inches in length.
Clay	c	Sticky and plastic when moist, produces a thin ribbon over 2 inches in length. Produces a high sheen when rubbed with the thumb nail and forms a strong ball resistant to breaking.

SOURCE: *Virginia Criteria and Methods for Sewage Handling and Disposal* (1989).

Soil color sample chips are displayed on individual color charts. Each chart is a constant hue and is designated by a symbol in the upper right hand corner of the chart (e.g., 10YR). An example of a Munsell color chart showing equivalent color names, value and chroma designations for the 10YR hue is presented in FIGURE 5.10. Vertically, the color value increases and becomes progressively lighter in equal steps from bottom to top. Chroma increases in the horizontal direction going from neutral gray on the left to higher chroma on the right. When writing the Munsell notation, the order is hue, value and chroma (e.g., 10YR 5/2). The soil chart should be used with natural sunlight in the field and with no shadows falling on the sample. Accurate comparisons with the color chips can be

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TABLE 5.4

NAME AND SIZE FOR ROCK FRAGMENTS IN SOILS

SHAPE	SIZE AND NAME			
Rounded, subrounded, angular or irregular	<3 inch diameter Gravel (Gravelly)	3–10 inch diameter Cobble (Cobbly)	10–24 inch diameter Stone (Stony)	>24 inch diameter Boulder (Bouldery)
Flat	<6 inch length Channer (Channery)	6–15 inch length Flagstone (Flaggy)	15–24 inch length Stone (Stony)	>24 inch length Boulder (Bouldery)

SOURCE: Soil Survey Staff (1981).

TABLE 5.5

ROCK FRAGMENT MODIFIERS TO SOIL TEXTURE

VOLUME ESTIMATES (percent)	ADJECTIVE NAME
<15	—
15–35	Gravelly loam, etc.
35–60	Very gravelly loam, etc.
>60	Extremely gravelly loam, etc.

SOURCE: Soil Survey Staff (1992a).

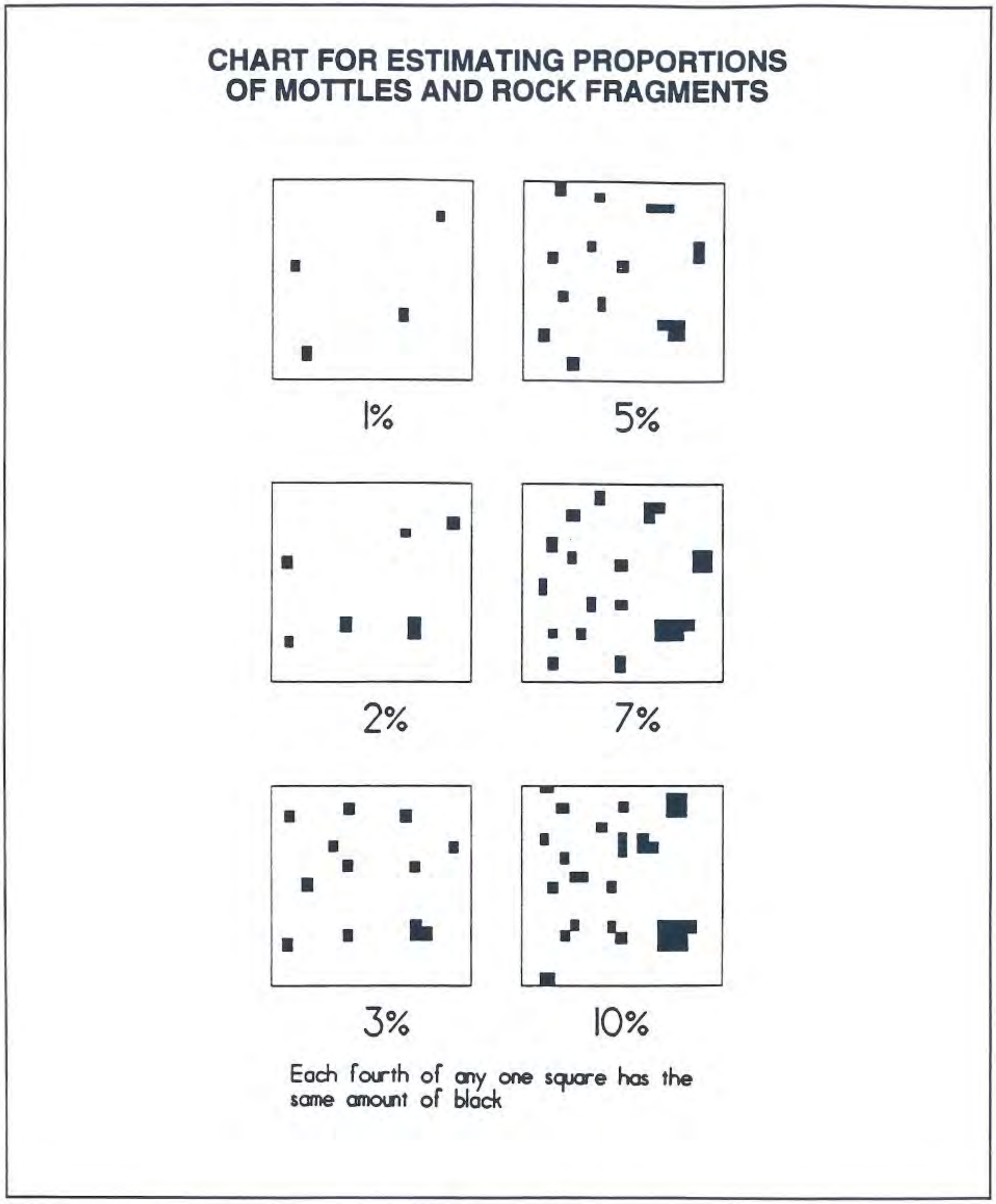
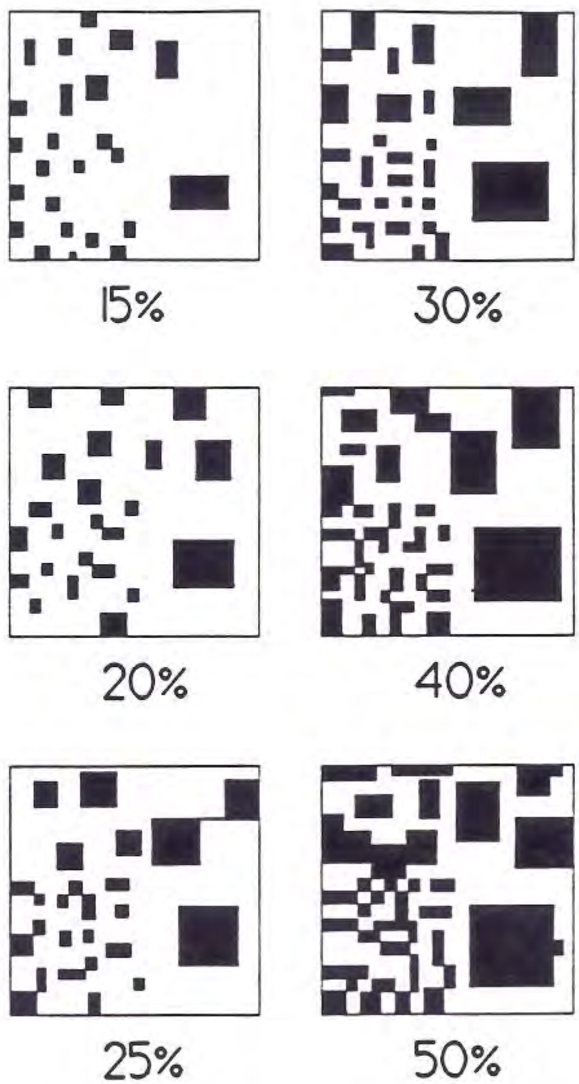


FIGURE 5.8

Chart for estimating rock fragments and mottles between 1 and 10 percent by volume.

CHART FOR ESTIMATING PROPORTIONS OF MOTTLES AND ROCK FRAGMENTS



Each fourth of any one square has the same amount of black

FIGURE 5.9

Chart for estimating rock fragments and mottles between 15 to 50 percent by volume.

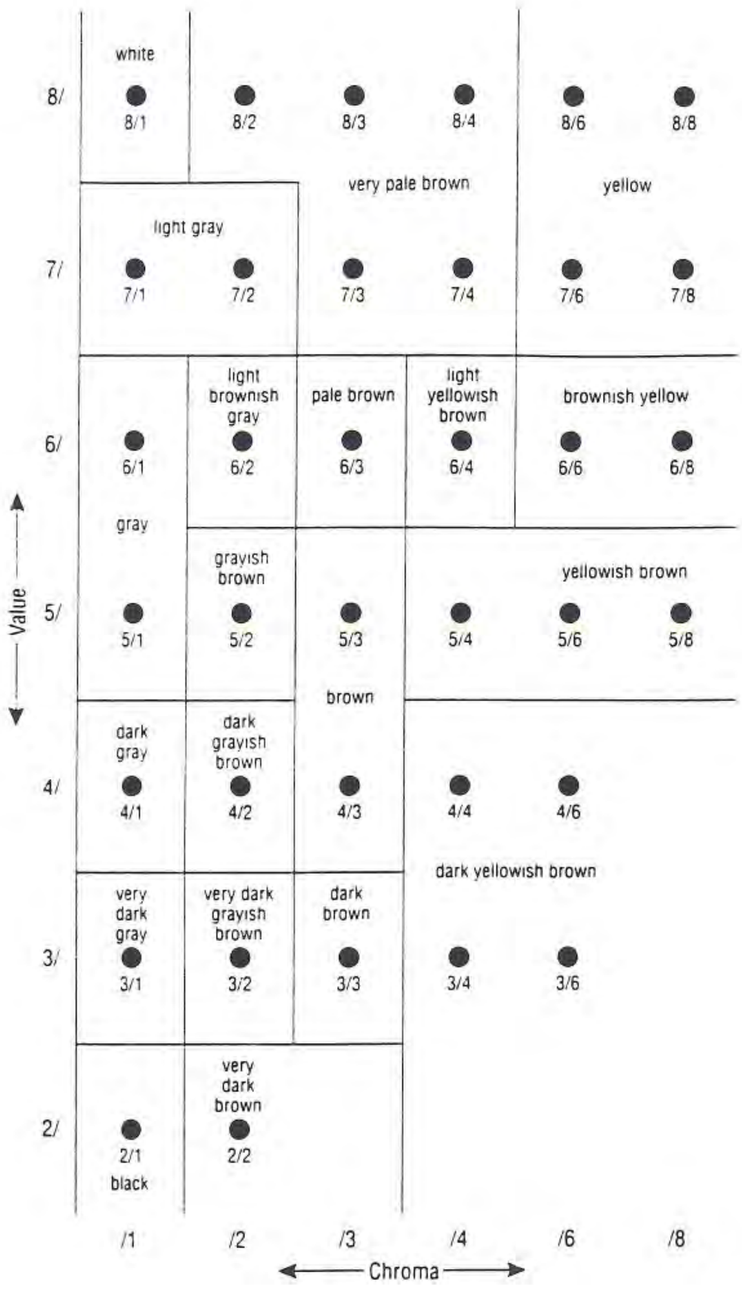


FIGURE 5.10

Example of Munsell soil color names and value and chroma designations for 10YR hue.

made by holding a moist soil ped or crushed soil sample directly behind the apertures separating the closest matching chips. Both dry and moist colors can be recorded, but the moisture condition must be identified. A perfect match is rare, but it is generally easy to determine which color chips the sample lies between and pick the closest match. A black mask can be used for dark samples and a gray mask for intermediate and light colors.

A soil horizon, substratum layer or saprolite may have a uniform color, or it may contain streaks, bands or spots of color. When more than one color is present, the dominant or matrix color occupies the greatest volume. The secondary colors may be related to specific features such as concretions, nodules, weathered and unweathered rock fragments, artifacts, fillings of animal burrows, roots and coatings on ped surfaces, or they may be less specific masses of spots and blotches of different color referred to as "mottles."

Mottles can be described in terms of quantity, size, contrast and color. Other properties that describe specific shapes, boundaries and locations can be recorded as needed.

Quantity: based on the percentage of the surface that is occupied by the mottle.

Size: approximate dimension of the mottles as observed on the surface.

Contrast: degree of visual distribution between associated colors of mottles and matrix.

Color: standardized Munsell color notation.

Quantity and size characteristics are presented in TABLE 5.6 and in detail for contrast classes in TABLE 5.7. These classes should be used to describe mottles observed for each soil horizon or layer and should be recorded on the soil profile description form as shown in FIGURE 5.4.

5.3.4.6 Soil Structure

Soil structure can have a significant influence on the soil's ability to transmit water. Soil structure refers to the aggregation of soil particles into clusters called "peds." Peds are separated by surfaces of weakensses with open planar pores between the peds that are often seen as cracks in the soil. Well-structured soils with large voids between peds will transmit water more rapidly than structureless soils of the same texture, particularly if the soil has become dry before the water is added. Fine-textured, massive soils, with little structure, have very slow percolation rates.

The type, size and stability of the peds depend on the arrangement of the soil particles and the bonds between the particles. The four major types of soil structure are platy, blocky, prismatic and granular. Detailed descriptions of types and grades of soil structure used by USDA–SCS are given in TABLES 5.8 and 5.9, and size classes for each type are illustrated in FIGURES 5.11, 5.12, 5.13, and 5.14.

Between the peds are voids which are often relatively large and continuous compared to the voids or pores between the primary particles within the peds. The type of structure determines the dominant direction of the pores and, hence, water movement in the soil. Platy structures restrict vertical percolation of water because cleavage faces are horizontally oriented. Prismatic and columnar structure enhance vertical water flow, while blocky and granular structures enhance flow both horizontally and vertically.

The size of structural units and their grade or durability can also affect water and air movement in the soil. Small structural units create more pores in the soil than large structural units. Soils with strong structure have distinct pores between peds. Soils with very weak structure, or soils without peds or planes of weakness, are said to be structureless and generally may have less distinct and durable secondary pores. Structureless sandy soils are called "single grained," while structureless soils with more clay content are called "massive."

Structure can be easily altered or destroyed by changes in response to moisture content, chemical composition of soil solution, biological activity and land management practices. Soils containing minerals that shrink and swell appreciably, such as montmorillonite clays, show particularly dramatic changes in structure. When the soil peds swell upon wetting, the large pores become smaller, and water movement through the soil is reduced. Swelling or a breakdown of structure can also result if the soil contains a high proportion of sodium salts. When determining the hydraulic properties of a soil for wastewater disposal, soil moisture contents and salt concentrations should be similar to that expected in the soil surrounding a disposal system (U.S. EPA, 1980).

TABLE 5.6

DESCRIPTION OF SOIL MOTTLES

GENERAL FEATURE	CLASS NAME	DESCRIPTION
Quantity	Few	<2% (observed surface)
	Common	2 to 20% (observed surface)
	Many	>20% (observed surface)
Size	Fine	<5mm in diameter
	Medium	5-15 mm in diameter
	Coarse	>15 mm in diameter

SOURCE: Soil Survey Staff (1951).

5.3.4.7 Soil Moisture

The moisture condition of a soil horizon or layer can be described as dry, moist or wet.

> **Dry:** soil is dry to the touch and changes color appreciably when water is applied. Soil water is held at tensions greater than 15 bars (>1500 kPa).
>
> **Moist:** soil feels moist to the touch, sample may leave stain on hands, no free water or water films visible. If slightly moist, the color may become perceptibly darker when water is applied. Soil water is held at tensions between 15 bars and 0.01 bar (1500 and 1 kPa).
>
> **Wet:** soil feels wet to the touch, prominent water films evident, free water may be present and flow out of the soil from large pores and cracks. Soil water is held at tensions 0.01 bar to near zero (<1 kPa).

These soil moisture conditions should be described and recorded for each horizon or layer observed.

5.3.4.8 Soil Consistence

Soil consistence describes the cohesion among soil particles and the adhesion of soil to other substances. Consistence may be described in terms of:

1) resistance to cracking or rupture when force is applied (strength);

2) force required to deform but not rupture soil material (plasticity);

TABLE 5.7

DESCRIPTIONS OF CONTRAST CLASSES FOR SOIL MOTTLES

GENERAL FEATURE	CLASS NAME	DESCRIPTION		
		HUE	VALUE	CHROMA
Contrast	Faint	same	no more than 2 *or*	no more than 1
	Distinct	same one page	3-4 *or* no more than 2 *or*	2-4 no more than 1
	Prominent	same one page two pages	at least 4 *or* at least 2 *or* same	at least 4 at least 1 same

SOURCE: USDA–SCS Maryland Office (1990).

TABLE 5.8

TYPES OF SOIL STRUCTURE

TYPE	GENERAL DESCRIPTIONS
Granular	Spheroidal and somewhat uniform with all three dimensions approximately equal. Surfaces somewhat rough with slight to no accommodations to faces of surrounding peds. If very porous also described as crumb. Commonly found in A- or Ap-horizons.
Platy	Plate-like with horizontal dimensions greater than vertical dimensions and faces mostly horizontal. May be found in any horizon or layer in the profile but commonly found in E- and Bx-horizons. If found in C horizons may be inherited from geologic materials and may be described as horizontal parting surfaces.
Blocky	Block-like with horizontal and vertical dimensions about the same, and surfaces of blocks are casts of molds formed by the faces of the surrounding peds. May be angular with faces flattened with sharp angles, or subangular blocky with mixed rounded and flattened faces. Commonly found in B-horizons.
Prismatic	Prism-like with vertical dimensions greater than horizontal dimensions, and vertical faces well defined.

SOURCE: Modified from Soil Survey Staff (1951).

TABLE 5.9

GRADES OF SOIL STRUCTURE

GRADE	CHARACTERISTICS
Structureless	No observable aggregation. If sandy, generally referred to as single grain. If finer textured, generally referred to as massive.
Weak	Poorly formed and difficult to see. Will not retain shape on handling.
Moderate	Evident but not distinct in undisturbed soil. Moderately durable on handling.
Strong	Visually distinct in undisturbed soil. Durable on handling.

SOURCE: Soil Survey Staff (1951).

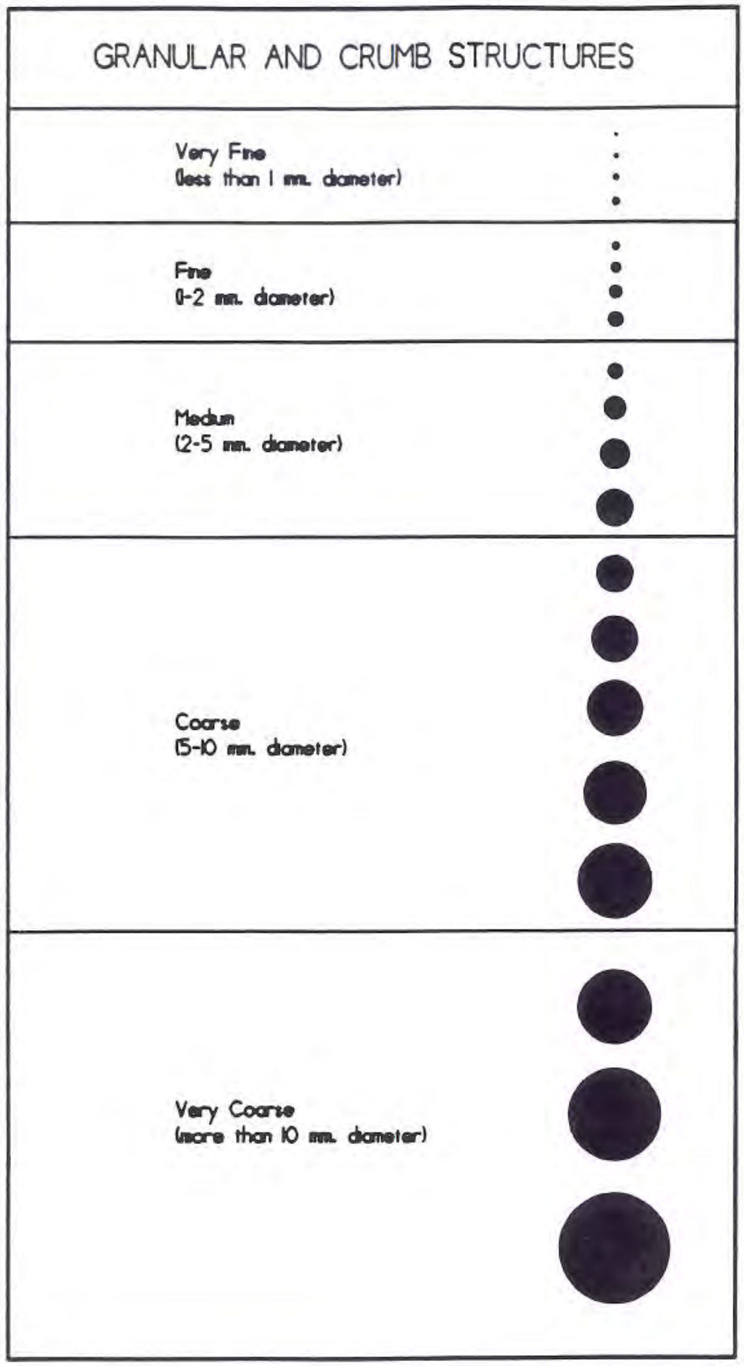


FIGURE 5.11
Chart for describing granular structure size class.

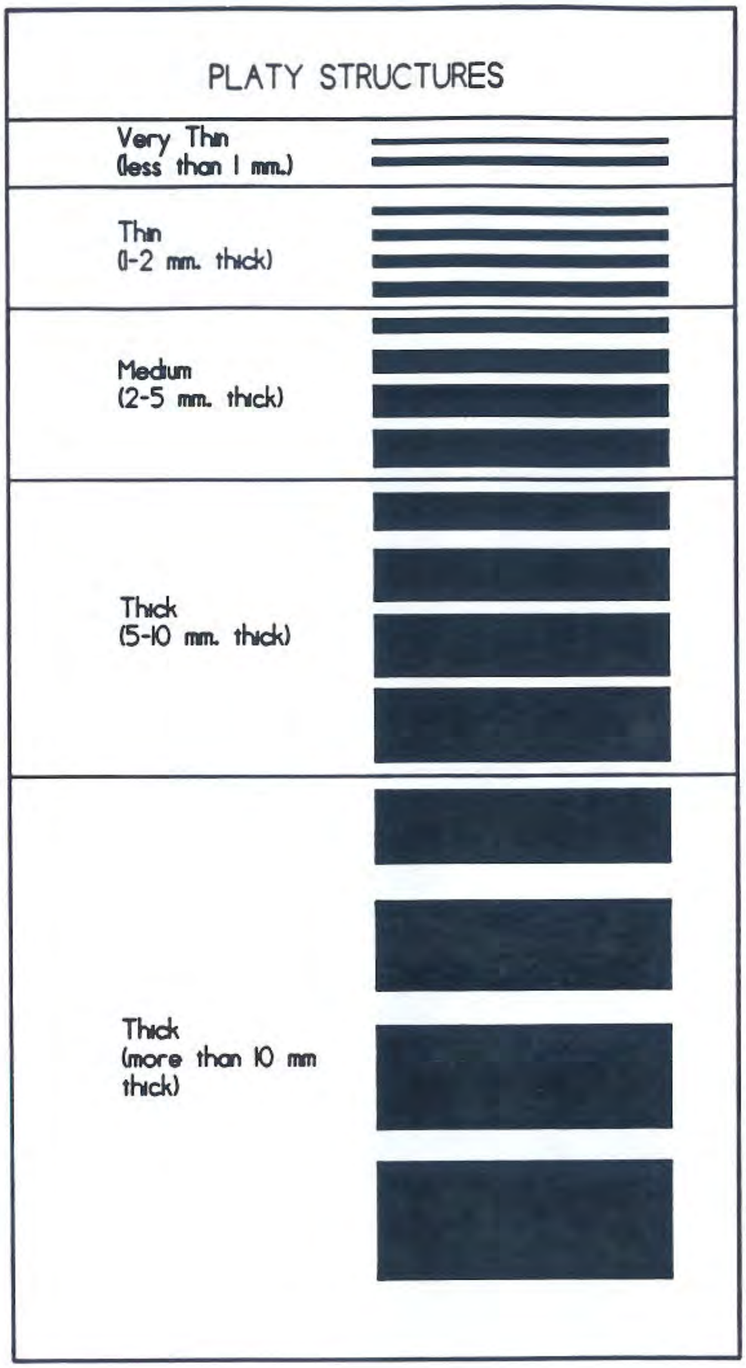


FIGURE 5.12

Chart for describing platy structure size class.

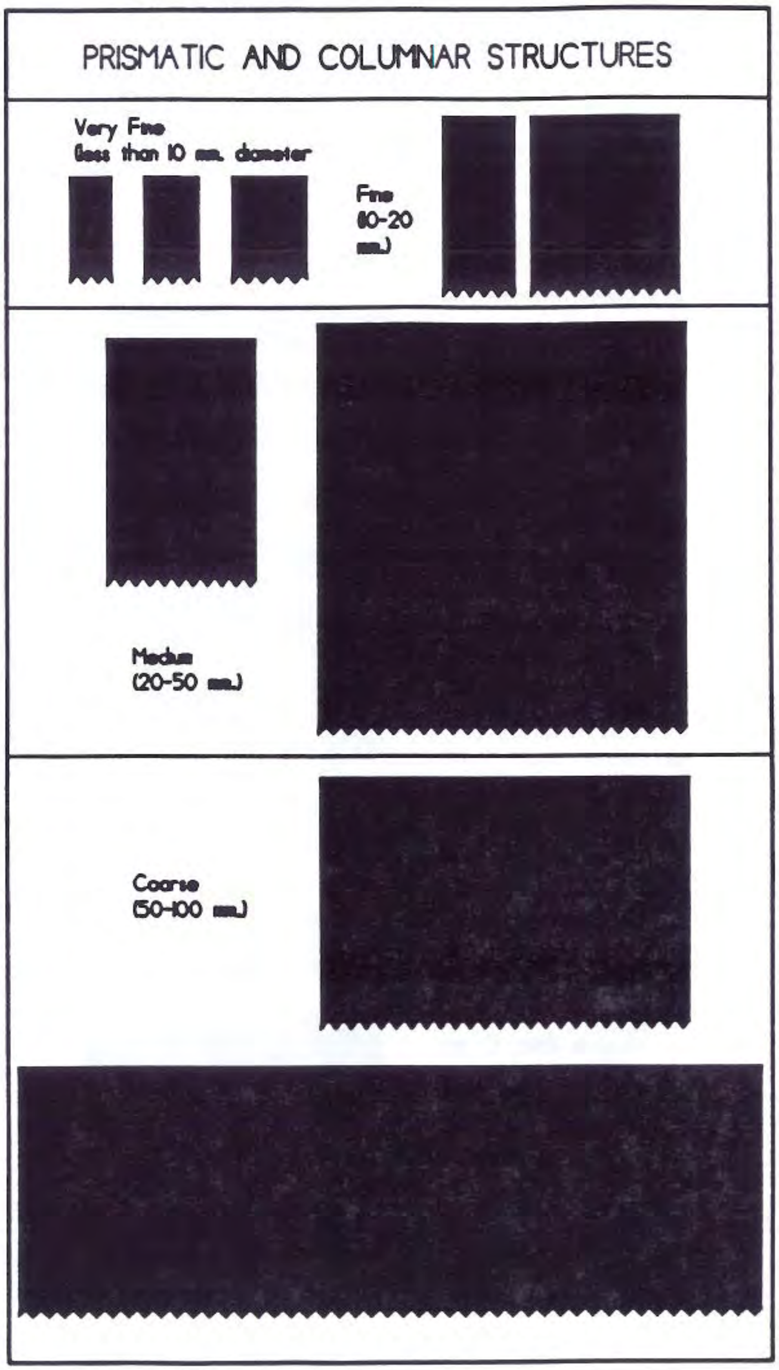


FIGURE 5.13
Chart for describing prismatic structure size class.

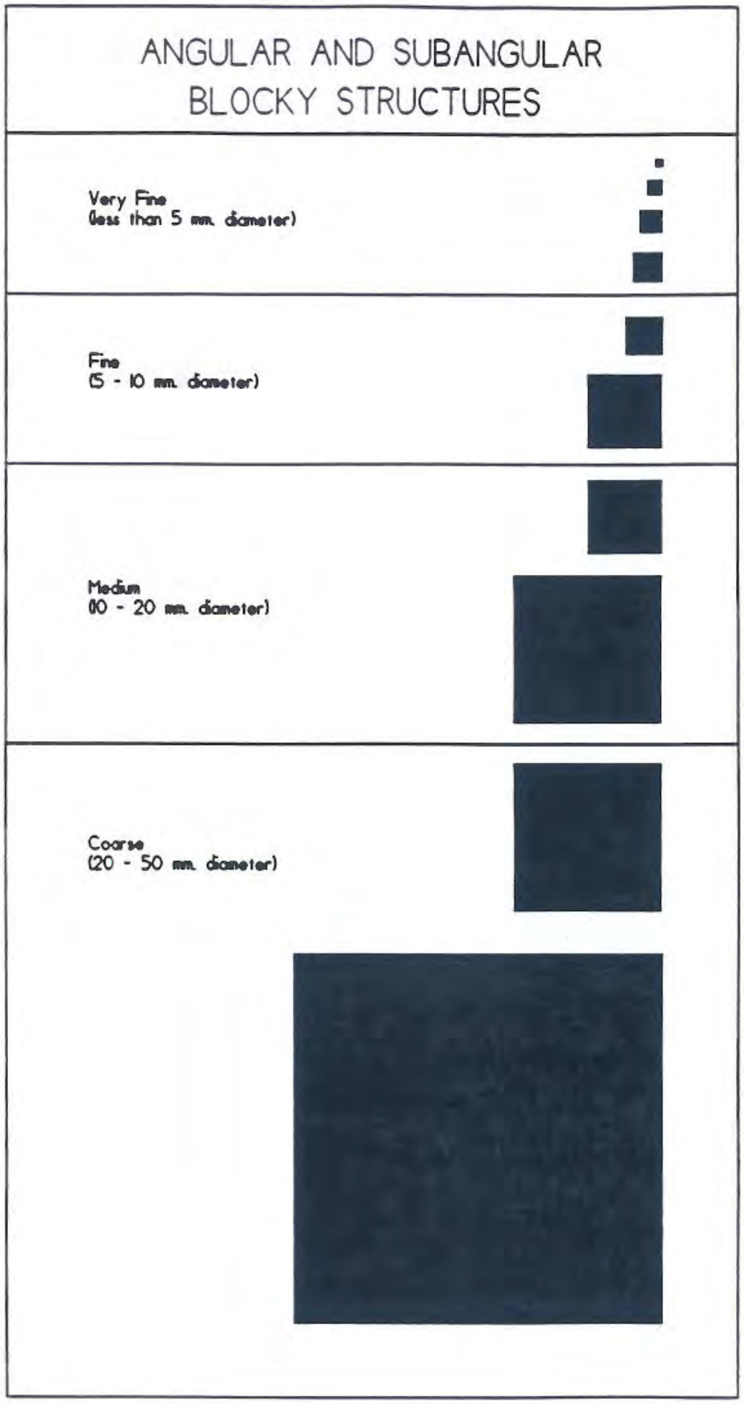


FIGURE 5.14
Chart for describing blocky structure size class.

3) degree to which soil material adheres to other objects (stickiness); and

4) behavior of soil material as it deforms when the force is applied (smeariness and fluidity).

For site evaluation soil descriptions it is recommended that consistence be described in terms of the first of these conditions: strength.

Soil strength is the degree of resistance to breaking or crushing when a force is applied and is evaluated under two different moisture conditions. The terms used to describe strength are specific to the moisture condition. When uncemented material is air dry, strength is described as loose, soft, slightly hard, hard, very hard or extremely hard. When at field moisture capacity strength is described as loose, very friable, friable, firm, very firm or extremely firm. Cemented material is evaluated [illegible] and after it has soaked for one hour and is described as weakly cemented, strongly cemented or [illegible]urated.

Use a cube of soil about 25–30 mm in each side or a ped of roughly the same size if possible. Squeeze the cube or ped on opposite vertical sides for no longer than 5 seconds. Use TABLE 5.10 to evaluate the force required to crush or break the sample and record for each horizon or layer described.

5.3.4.9 Surface Features

Surface features of some soil materials may differ from adjacent soil material in composition, orientation or packing. Surface features include:

1) coatings that are not like the adjacent soil material and may cover part or all of the surface;

2) material concentrated on surfaces by the removal of other material; and

3) stress features in which thin surface layers have undergone reorientation or packing.

Descriptions of surface features may include type, location, amount, distinctness, continuity, and thickness. In addition, color and texture may be described if distinctly different from adjacent soil materials. Terms used to describe surface features are as follows:

Type: surface features are distinguished by difference in texture, color, packing, orientation of particles or reaction to various tests.

- *Clay skins,* also referred to as clay films, are thin layers of oriented translocated clay.

- *Sand or silt coatings* are sand or silt grains that adhere to a surface.

- *Other coatings* may be composed of iron, manganese oxides, organic matter, salts or carbonates. Field tests can be used to tentatively identify features, if necessary.

- *Stress surfaces* are smoothed surfaces with greater density than adjacent soil. Stress surfaces are generally caused by pressure and may persist through successive drying and wetting cycles.

- *Slickensides* denotes polished and striated stress surfaces typically produced by one mass of soil sliding over another and are common in swelling clays with marked changes in moisture content.

Location: features may occur on horizontal or vertical surfaces of peds, channels, pores, individual grains, rock fragments, nodules or concretions.

TABLE 5.10

GUIDE FOR DESCRIBING SOIL CONSISTENCE

FIELD METHOD DESCRIPTION	CONSISTENCE	
	DRY	MOIST
No specimen can be obtained.	Loose	Loose
Specimen crushes or breaks when very slight force applied by thumb and forefinger.	Soft	Very Friable
Specimen crushes or breaks when slight force applied by thumb or forefinger.	Slightly Hard	Friable
Specimen crushes or breaks when moderate force applied by thumb or forefinger.	Moderately Hard	Firm
Specimen crushes or breaks when strong force applied by thumb or forefinger.	Hard	Very Firm
Specimen cannot be crushed or broken by thumb or forefinger but can be broken or crushed by squeezing slowly between hands.	Very Hard	Extremely Firm
Specimen cannot be crushed or broken in hands but can be broken or crushed underfoot by person weighing 80 kg applying weight slowly.	Extremely Hard	Slightly Rigid

SOURCE: Modified from Soil Survey Staff (1981) and Soil Survey Staff (1993).

Amount: area occupied by a type of surface feature over the extent of the horizon is described. Amount can be described by the following classes:

- *Very few* - occupies less than 5 percent of the total area of the kind of surface described.
- *Few* - occupies 5 to 25 percent of the total area of the kind of surface described.
- *Common* - occupies 25 to 50 percent of the total area of the kind of surface described.
- *Many* - occupies more than 50 percent of the total area of the kind of surface described.

Distinctness: refers to the ease and degree of certainty with which a feature can be identified. Distinctness is related to thickness, color contrast, and properties. The distinctness of some surface features changes with amount of moisture, therefore the soil–water state is specified. Three distinctness classes are used:

- *Faint* - evident only on close examination with 10X magnification.
- *Distinct* - can be detected without magnification. The feature contrasts enough with the adjacent material that a difference in color, texture or other properties is evident.
- *Prominent* - conspicuous without magnification when compared with a surface broken through the soil. Color, texture, thickness or some other property or combination of properties contrasts sharply with properties of the adjacent material.

5.3.4.10 Soil Pores

Pores are created primarily by the packing, arrangement and aggregation of primary particles, roots, burrowing insects, worms and other animals.

Pore space in soils can be considered as an interconnected network of voids extending in all directions. The voids hold liquids and gases, and regulate their movement, contain most of the living organisms in the soil, and provide space for roots to develop. When soil contains free water, the movement of water is very closely related to the continuity and the size of the pores. Descriptions of texture, structure, color, consistence and root distribution can be used to infer conditions related to pore size and continuity and how it may affect water movement.

When describing soils for on-site sewage disposal systems, pores should be described and recorded if they have the potential for affecting water movement. Pores can be described in terms of size, quantity, and shape as follows:

Size: four size classes are described:

- *Very fine* - less than 0.5 mm in diameter.
- *Fine* - 0.5 to 2 mm in diameter.
- *Medium* - 2 to 5 mm in diameter.
- *Coarse* - more than 5 mm in diameter.

Quantity: classes are defined by the estimated numbers of each kind and size of pore per unit area. For very fine and fine pores the unit area is 1 cm^2, and for medium and coarse pores the unit area is 1 dm^2. All pores smaller than 10 mm in diameter can be described using the following classes:

- *Few* - less than 1 per unit area of the specified size.
- *Common* - 1 to 5 per unit area of the specified size.
- *Many* - more than 5 per unit area of the specified size.

Shape: most pores described will be either vesicular (approximately spherical or elliptical) or tubular (approximately cylindrical and elongated). Some are irregularly shaped and can be described as irregular.

5.3.4.11 Cementation

Soil material with hard or very firm consistence may be the result of some cementing agent other than clay minerals. Other cementing agents might include oxides of iron, silica, organic matter and calcium carbonate. It may be necessary to compile additional field notes when cementing conditions are encountered or suspected.

Cementation is not generally altered significantly by wetting. If cementation is significantly altered by wetting this should be recorded in the field notes. The following classes of cementation should be used when preparing soil descriptions:

- *Weakly cemented* - material is brittle and hard but can be broken by hands.
- *Strongly cemented* - material is brittle and harder but can be broken easily with a hammer.
- *Indurated* - material is strongly cemented, does not soften under prolonged wetting and is so hard that a sharp blow from a hammer is required for breakage.

Soil horizons or layers that are indurated are often referred to as pans although not all soils within pans are indurated (i.e., fragipans).

5.3.4.12 Additional Remarks

Additional features that may affect water movement, treatment capacity or system installation should be noted and recorded when describing soil horizons, substratum layers and saprolite. Items that should be noted include:

- depth to apparent or perched groundwater;
- presence and extent of ironstone;
- rock outcrops or ledges;
- fractured, creviced or consolidated bedrock;
- Fe and Mn concretions;
- clay films and coatings;
- caving;
- structured saprolite; and
- geologic materials.

5.3.5 Inferences Based on Soil Morphological Data

5.3.5.1 Hydraulic Conductivity Estimates

Estimates of saturated vertical hydraulic conductivity can be made based on soil morphological properties and correlations that have been made between soil properties and hydraulic conductivity measurements (Soil Survey Staff, 1981). TABLE 5.11 can be used to make estimates for each soil horizon and layer that is described. Based on these estimates, the depths of the least permeable solum horizons and most restrictive substratum layers should be identified and recorded on the soil profile description form as shown in FIGURE 5.4.

5.3.5.2 Soil Wetness and Drainage Classes

Soil wetness is influenced by climate, landscape position, slope and other characteristics of the soil. The amount of precipitation, infiltration, runoff, evaporation, and subsurface seepage and the rate of water movement through the soil affect the degree and duration of wetness. Although soil

TABLE 5.11

GUIDE FOR ESTIMATING SATURATED VERTICAL HYDRAULIC CONDUCTIVITY

CLASS NAME	RATE (in./hr.)	SOIL PROPERTIES
Very high	>14	Fragmental Sandy with coarse sand or sand texture and loose consistence More than 0.5 percent medium or coarser vertical pores with high continuity
High	1.4–14	Other sandy, sandy-skeletal, or coarse-loamy soil material with very friable, friable, soft or loose consistence When very moist or wet has moderate or strong granular structure, or strong blocky structure of any size, or prismatic finer than very coarse, and many surface features except stress surfaces or slickensides on vertical surfaces of structural units 0.5 to 0.2 percent medium or coarser vertical pores with high continuity
Moderate	0.14–1.4	Sandy with other consistence classes except extremely firm or cemented 18 to 35 percent clay with moderate structure except platy or with strong, very coarse prismatic and with common surface features except stress surfaces or slickensides on vertical surfaces of structural units 0.1 to 0.2 percent medium or coarser vertical pores with high continuity
Moderately low	0.014–0.14	Other sandy classes that are extremely firm or cemented, 18 to 35 percent clay with other structures and surface conditions except pressure or stress surfaces ≥35 percent clay and moderate structure except if platy or very coarse prismatic, and with common vertical surface features except stress surfaces or slickensides Medium or coarser vertical pores with high continuity percent but <0.1 percent
Low	0.0014–0.014	Continuous moderate or weak cementation ≥35 percent clay and meets one of the following: weak structure; weak structure with few or no vertical surface features; platy structure; common or many stress surfaces or slickensides
Very low	<0.0014	Continuous indurated or strongly cemented and less than common roots ≥35 percent clay and massive or exhibits horizontal depositional strata and less than common roots

SOURCE: Soil Survey Staff (1981).

wetness and depth to saturation change from year to year and throughout the year, most soils have typical times and depths of wet (i.e., near-saturation) or field saturated conditions.

Soils that currently experience continuous or periodic saturation and reduction (i.e., aquic conditions) may exhibit characteristic morphological color patterns and redoximorphic features. These wetness-related color patterns have been correlated with the reduction and oxidation of iron (Fe) and manganese (Mn) ions and their movement within the soil. Reduced Fe and Mn are mobile and may be transported by water. Certain redox patterns occur as a function of where the ion-carrying water moves in the soil and the location of aerated zones where oxidation occurs. Redox patterns are also affected because Mn is reduced more rapidly than Fe, and Fe oxidizes more rapidly upon aeration. The reduced Fe and Mn ions may be transferred or removed from the soil by lateral and vertical water movement (i.e., redox depletions), or they may oxidize and precipate as soft masses or hard concretions and nodules (i.e., redox concentrations)(Soil Survey Staff, 1992b).

The depth and duration of saturation along with reducing conditions can be related to the color, quantity, location and pattern of redoximorphic features. Redoximorphic features include both high chroma and low chroma (≤ 2) wetness mottles and are summarized in TABLE 5.12. Not all saturated soils have morphological properties reflecting wetness. Saturation can occur without producing reducing conditions and redoximorphic features. This can occur when water is oxygen-rich, when temperatures are low or when there is an absence of energy sources necessary for redox reactions. Also redoximorphic features and wetness mottles may be a relict feature related to past drainage conditions.

TABLE 5.12

DESCRIPTION OF REDOXIMORPHIC FEATURES

REDOXIMORPHIC FEATURES	DESCRIPTION
Redox concentrations	Zones of apparent accumulation of Fe-Mn oxides including nodules, concretions, masses and pore linings
Redox depletions	Zones of low chroma (≤ 2) where Fe-Mn oxides are low and include: (1) iron depletion zones that contain low amounts of Fe-Mn oxides but with clay content similar to matrix, and (2) clay depletion zones that contain low amounts of Fe-Mn and clay
Reduced matrix	Soil matrix with low chroma *in situ* but hue or chroma increases within 30 minutes after exposure to air

SOURCE: Soil Survey Staff (1992b).

Soil wetness conditions can also be summarized using soil drainage classes developed for local areas. The drainage classes are somewhat relative within a given area and generally are related to runoff, infiltration, hydraulic conductivity and internal soil water movement. Seven classes are recognized by the USDA–SCS and can be described generally as follows:

Excessively drained soils have very high and high hydraulic conductivity and low water holding capacity.

Somewhat excessively drained soils have high hydraulic conductivity and low water holding capacity.

Well drained soils have intermediate water holding capacity. They retain optimum amounts of moisture, but are not wet close enough to the surface or long enough during the growing season to adversely affect yields and use for many purposes.

Moderately well drained soils commonly have a layer with low hydraulic conductivity, wet state relatively high in the profile, additions of water by seepage, or some combination of these conditions.

Somewhat poorly drained soils commonly have a layer with low hydraulic conductivity, wet state high in the profile, additions of water through seepage, or a combination of these conditions.

Poorly drained soils commonly are wet at or near the surface during a considerable part of the year. Poorly drained conditions are caused by a saturated zone, a layer with low hydraulic conductivity, seepage, or a combination of these conditions.

Very poorly drained soils are wet to the surface most of the time.

TABLE 5.13 presents additional morphological criteria used by the USDA–SCS in Maryland to differentiate drainage classes.

5.3.5.3 Identification of Limiting Zones

Limiting zones can be defined as any horizon, layer, characteristic or condition of the soil that will limit the capability of the soil to transmit, absorb or renovate effluent. Limiting zones include the following:

Seasonal high water table - perched or apparent, determined by direct piezometer measurement during the wet season and representative of maximum height of water for normal or near normal precipitation. Estimated by depth in soil of wetness-related mottles with ≤ 2 chroma (i.e., aquic conditions and associated redoximorphic features as defined by Soil Survey Staff, 1992b).

Fractured rock - rock with open joints, fractures or solution channels. Soil and rock fragments >50 percent by volume with insufficient soil to fill the voids between fragments and with percolation rate faster than 2 minutes per inch, or saturated hydraulic conductivity estimates equal to or faster than 14 inches per hour.

Restrictive layer - consolidated rock, fragipans, ironstone layers, substratum layers or soil conditions that effectively limit downward movement of water and wastewater. Includes horizons and layers with moderate or strong platy structure; moist consistence stronger than firm or cemented; soil material with textures of sandy clay, clay or silty clay with weak or massive soil structure; abrupt or strongly contrasting particle size changes or horizons or layers with saturated hydraulic conductivity estimates less then 0.14 inches per hour.

Data from the soil profile descriptions should be used to identify the absence or presence of any limiting zones and the approximate depths of these limiting zones. Any limiting zones that are detected should be recorded on the soil profile description form as shown in FIGURE 5.4.

5.4 SOIL HYDRAULIC PROPERTIES AND TESTS

5.4.1 Background

Soil hydraulic properties involve the distribution and flow of water under unsaturated and saturated conditions, and include soil–water characteristic curves (soil–water content vs. matrix potential or

TABLE 5.13

USDA–SCS SOIL DRAINAGE CLASSES

DRAINAGE CLASS	GENERAL DESCRIPTION
Excessively drained	Mottling deeper than 40 inches, very rapid permeability (sands)
Somewhat excessively drained	Mottling deeper than 40 inches, rapid permeability (loamy sands)
Well drained	Mottling deeper than 40 inches
Moderately well drained	Gray mottles (≤2 chroma) between 20 to 40 inches
Somewhat poorly drained	Gray mottles (≤2 chroma) between 10 to 20 inches
Poorly drained	Gray colors (≤2 chroma) and/or red mottles within upper 10 inches with predominantly gray matrix (>60%) below 10 inches
Very poorly drained	Very dark or black surface with gray subsoils

SOURCE: USDA–SCS Maryland State Office (1990).

tension), hydraulic conductivity, infiltration rates, available water holding capacity, aquifer transmissivity and storage coefficients or specific yield.

The distribution of water depends on the characteristics of the soil pores, while movement is determined by the relative energy status of the water (U.S. EPA, 1980; Bouma et al., 1982; Hillel, 1982; Bouwer, 1978; Otis, 1980). Water moves in soil in response to differences in energy status. The energy status or potential at a given temperature can be primarily expressed as the gravitational potential plus matrix potential. Gravitational potential is a result of position while matrix potential is a result of the capillary forces produced by the attraction of water molecules to each other and to solid surfaces.

Matrix forces hold water in soil against gravity with pressures less than atmospheric and thus are considered negative pressure. This negative pressure can also be referred to as soil suction or soil moisture tension, which is a positive quantity. Increasing suction is associated with soil drying, and the matrix potential is zero when the soil is saturated (U.S. EPA, 1980). Water is held tighter in small pores than in larger pores, and upon drainage the larger pores will drain first. When soils are unsaturated, water is held in the finer pores.

Water movement in soils is proportional to the energy gradient or driving force and is dependent on the soil's hydraulic conductivity. This relationship can be described by Darcy's Law and applies to both saturated and unsaturated conditions. The hydraulic conductivity is related to the number, size and configuration of soil pores. Under saturated conditions soils with large pores can transmit water rapidly and have a high saturated hydraulic conductivity. Under unsaturated conditions pressure potentials are negative, air is present in some of the larger pores and the flow conditions are altered. Unsaturated flow becomes tortuous, and the primary forces operating are capillary. Consequently, unsaturated conductivity of a soil is much lower than saturated conductivity. Additional discussions of unsaturated flow and its relationship to long-term wastewater acceptance rates are provided in Bouma (1975), Healy and Laak (1975) and a number of other references.

Relatively accurate characterization of water movement in soils can be accomplished by describing soils in detail, measuring saturated and unsaturated conductivity and applying known principles of water flow. These principles have been applied by a number of researchers to site evaluations for on-site wastewater disposal and for selecting wastewater loading rates for design. However, these techniques currently are not used widely in daily operations of most regulatory authorities. Measurements are generally time consuming, and accurate application requires considerable knowledge of soil water and groundwater flow theory. A detailed discussion of these topics is beyond the scope of this document. Users of this manual are encouraged to consult the references listed in APPENDIX A for additional reading.

The following sections discuss commonly-used field techniques for measuring percolation rates and for assessing the relative capacity of the soil to accept and transmit water and wastewater.

5.4.2 Percolation Tests

5.4.2.1 Standard Falling Head Test

A standard falling head percolation test measures the time required for a unit depth of clear water to infiltrate into the soil from a standard size uncased hole. The percolation test rate is expressed as the number of minutes for the water to fall one inch (i.e., minutes per inch or MPI).

Percolation test procedures were first described by Henry Ryon of the New York Health Department (Ryon, 1928). The percolation rates measured by his test were correlated with actual system performance and the ability of the soil to accept septic tank effluent. Using these general correlations Ryon made recommendations on absorption area requirements and site suitability. Ryon's method was subsequently adapted throughout much of the United States and was studied in more detail by the U.S. Public Health Service and the University of California (Weibel et al., 1949; Bendixen et al., 1950; Weibel et al., 1954; Winneberger et al., 1960; Coulter et al., 1960; McGauhey and Winneberger, 1963; McGauhey and Winneberger, 1965). These studies resulted in recommendations for improved practices involving site evaluations and changes in the percolation test method. The results were published in the *Manual of Septic Tank Practice* published by the U.S. Public Health Service (USPHS) in 1957 and revised in 1967 (USPHS, 1967).

A standard test procedure recommended for use in Maryland was published by the State of Maryland Department of Health (MDH) in 1954 (MDH, 1954). The procedure involved digging a test pit, approximately 3 feet deep or at the same depth as the proposed trench bottom, and conducting a percolation test in a 1 foot square hole. The square hole was filled with water to a depth of 7 inches and the water level allowed to drop to 6 inches for pre-wetting. The time required for the water level to drop from 6 inches to 5 inches was measured and designated the percolation test rate.

The percolation test method, the procedures used and the variability of the results have been studied and discussed by a number of authors (Bouma et al., 1975; Bouma, 1975; Derr et al., 1969; Bouma, 1971; Healy and Laak, 1973; National Environmental Health Association, 1979). Based on these studies, percolation rates can vary according to test hole diameter, water depth during testing, presoaking methods, gravel use, procedures for hole preparation and procedures for determining rates (National Environmental Health Association, 1979). The test method can be described as a three-dimensional infiltration measurement for a partially-saturated soil under variable head conditions (Fritton et al., 1986). The test produces highly variable results, and the rates are not physical constants because of variable and unknown boundary conditions in the surrounding volume of soil and the flow system in the vicinity of the test.

The percolation test, however, is still used because of a lack of a better test and because the test proved useful in ranking different soils according to their relative capacity to transmit liquid.

The results of the percolation test are interpreted empirically to confirm soil suitability and select wastewater loading rates for shallow and deep trench system design. A description of the standard percolation test used in Maryland is provided in APPENDIX I. An example percolation test data form is given in FIGURE 5.15. Considering the empirical nature of the test and the variable results, the test procedure outlined in APPENDIX I should be followed as closely as possible.

5.4.2.2 Single Ring Infiltrometer Test

The single ring falling head infiltrometer test used in Maryland measures the time required for a unit depth of clear water to infiltrate into the soil from a standard size infiltrometer. The infiltration rate is influenced by saturated hydraulic conductivity as well as capillary effects or matrix potential of the surrounding soil. The magnitude of the matrix potential effect is determined by a number of factors including the initial soil moisture content at the time of testing, pore size, texture, structure, entrapped air, fluid and soil temperature and chemistry of the water. The single ring infiltrometer test used in Maryland is a modification of standard methods reported in the literature (Bertrand, 1965; Bouwer, 1986; ASTM Committee, 1988; ASTM Designation: D5126-90, 1990). The modified test method is used to measure an approximate stabilized infiltration rate of selected soil horizons or layers that are estimated to control vertical water flow through the profile. The modified method is presented in APPENDIX J.

5.4.3 Hydraulic Conductivity Tests

Hydraulic conductivity tests can be used to characterize water movement in the soil and surrounding groundwater flow system. A number of methods are available for measuring both saturated and unsaturated hydraulic conductivity (ASTM Designation: D5126-90, 1990; Boersma, 1965a; Boersma, 1965b; Amoozegar and Warwick, 1986; Green et al., 1986). Methods available for measuring field saturated hydraulic conductivity can be grouped into those used above the water table and those used below the water table (ASTM Designation: D5126-90, 1990; Boersma, 1965a; Boersma, 1965b). Common methods include single ring and double ring infiltrometers, air-entry permeameters, borehole permeameters, auger holes, piezometers, slug tests and pumping tests. Methods used to measure and estimate unsaturated hydraulic conductivity include instantaneous profile, gypsum crust and borehole permeameter data, tension infiltrometers and laboratory data relating water content to matrix potential and hydraulic conductivity.

Field measurements that maximize the volume of soil tested and that best simulate potential flow systems for operating systems are preferred. A comprehensive discussion of these test methods is beyond the scope of this document. The users of this manual should refer to the references given in APPENDIX A for additional reading.

Currently, field saturated hydraulic conductivity tests are used in the State to help determine soil and substratum suitability for sand-lined trench systems, bermed infiltration ponds and groundwater mounding analysis when required for clustered systems. The tests most commonly used are the slug and piezometer method (Boersma, 1965b; Green et al., 1986). MDE's guidance for using these tests is presented in APPENDIX K.

MARYLAND DEPT. OF THE ENVIRONMENT ONSITE SEWAGE DISPOSAL PERMIT SITE EVALUATION REPORT PERCOLATION TEST DATA	FILE NO. WO-200-SE-90 MD GRID: N180/E1340 COUNTY: WORCESTER TAX MAP/B/P:103/B/65 SUBDIVISION: HILLTOP

LOT 2 SECTION 1

METHOD	SINGLE RING INFILTROMETER			BY:	P.Servant	
DATE	4-12-91	SOIL - SCL-L	2msbk fr	WEATHER:	SUNNY 70 F	
DEPTH	18 in.	HOLE DIA.(in.)	12	CONV. FACTOR		
TEST NO.	ELAPSED TIME	TIME INTERVAL (min.)	WATER LEVEL (in.)	DROP IN WATER LEVEL (in.)	RATE (min/in.)	REMARKS
R1	0		7.00			7 in. head
	9.99	9.99	6.00	1.00	9.99	
	25.45	15.46	5.00	1.00	15.46	
	30.91		6.00			6 in. head
	47.75	16.84	5.00	1.00	16.84	
				TEST RATE	17	

METHOD	SINGLE RING INFILTROMETER			BY:	P.Servant	
DATE	4-12-91	SOIL - L	1msbk fr	WEATHER:	SUNNY 70 F	
DEPTH	14 in.	HOLE DIA.(in.)	12	CONV. FACTOR		
TEST NO. R2	ELAPSED TIME	TIME INTERVAL (min.)	WATER LEVEL (in.)	DROP IN WATER LEVEL (in.)	RATE (min/in.)	REMARKS
	0		7.00			7 in. head
	24.82	24.82	6.00	1.00	24.82	
	56.00	31.18	5.00	1.00	31.18	
	60.68		6.00			6 in. head
	91.89	31.21	5.00	1.00	31.21	
				TEST RATE	31	

METHOD	SINGLE RING INFILTROMETER			BY:	P.Servant	
DATE	4-12-91	SOIL - L	2msbk fr	WEATHER:	SUNNY 70 F	
DEPTH	14 in.	HOLE DIA.(in.)	12	CONV. FACTOR		
TEST NO.	ELAPSED TIME	TIME INTERVAL (min.)	WATER LEVEL (in.)	DROP IN WATER LEVEL (in.)	RATE (min/in.)	REMARKS
R3	0		7.00			7 in. head
	10.12	10.12	6.00	1.00	10.12	
	21.90	11.78	5.00	1.00	11.78	
	25.16		6.00			6 in. head
	38.30	13.14	5.00	1.00	13.14	
	41.52		6.00			6 in. head
	56.18	14.66	5.00	1.00	14.66	
				TEST RATE	15	
				AVE.RATE	21	

FIGURE 5.15

Example percolation test form.

6.0 STEP 4: SUITABILITY RECOMMENDATIONS

6.1 OBJECTIVES

Data collected from the application review, preliminary evaluation and field investigation should be used to assess site and soil suitability and make final recommendations. The main objectives are to:

1) Confirm that the site and soil properties meet all regulatory requirements or conditions for variances outlined in appropriate regulations.

2) Assess the influence of landscape features and soil properties on water and wastewater movement.

3) Determine whether the proposed SDA(s) is suitable and select an on-site sewage disposal system that will function hydraulically and maximize treatment.

4) Provide recommendations that can be used in the design and construction of the selected system.

6.2 SUITABILITY ASSESSMENT

Data collected in the field may be used with TABLE 6.1 and the summary checklist provided in TABLE 6.2 to confirm regulatory requirements, assess site features and soil properties, and select system disposal types. The suitability assessment should be done in the field concurrently with data collection.

6.3 RECOMMENDATIONS

The example recommendation form in FIGURE 6.1 should be used with TABLES 6.1 and 6.2 to provide final recommendations for system design and any necessary site modifications. TABLE 6.3 can be used to estimate wastewater loading rates for sites with failing systems that cannot meet existing percolation test requirements (Tyler et al., 1991).

TABLE 6.1

SITE EVALUATION SUITABILITY ASSESSMENT

PROPERTY	POTENTIAL LIMITING CONDITION	POSSIBLE ACTION
Horizontal setbacks, well location, fill and floodplain soils	– SDA does not meet minimum distance requirements or is upslope of well location	– Eliminate non-conforming area – Move SDA – Divide SDA into usable, non-contiguous areas – If appropriate, recommend variance or additional testing
Landscape position	– SDA within footslope, toeslope or lower a of slope	– Move SDA upslope – Document lateral water movement problem and install upslope interceptor drain, if feasible
Seasonal high groundwater	– <2 ft. below land surface – <4 ft. below trench bottom infiltrative surface – Inadequate unsaturated soil treatment zone	– Eliminate non-conforming area – Move trench bottom to acceptable depth or test for sand mound
Rock fragment content	– >50% by volume in the unsaturated soil treatment zone	– Eliminate non-conforming area – Move SDA – Divide SDA into non-contiguous areas
Texture	– c, sc, sic with weak or massive structure – sl, ls and s or cl, sil, sicl, scl with <50% rock fragments and strong structure	– Eliminate from trench suitable absorption area calculation – Adjust trench bottom elevation to maintain > or = 3 ft. vertical separation – Conduct percolation test, option to use extended pre-wet or USPHS test for cl, sicl, sil and scl
Structure	– Moderate to strong platy structure and cementation	– Eliminate from trench suitable absorption area calculation – Adjust trench bottom elevation to maintain > or = 3 ft. vertical separation – Eliminate non-conforming area – Move SDA – Divide SDA into non-contiguous areas
Consistence	– Very firm or greater and cementation	– Eliminate from trench suitable absorption area calculation – Adjust trench bottom elevation to maintain > or = 3 ft. vertical separation – Eliminate non-conforming area – Move SDA – Divide SDA into non-contiguous areas

TABLE 6.2

SITE EVALUATION SUMMARY CHECKLIST

ITEM	STATUS	LIMITING CONDITION
PRELIMINARY EVALUATION		
Background Review		
Property category		
Wastewater characterization		
Soil survey report		
Topographic maps		
Hydrogeologic reports		
Monitoring well network		
Local records		
Sanitary surveys		
Well problems		
System failures		
FIELD INVESTIGATION		
Site reconnaissance		
Property boundaries		
SDA 1 - Existing/proposed		
SDA 2 - Alternative		
Buildings on-site		
Buildings off-site		
Wells on-site		
Wells off-site		
Slope		
Streams		
Springs		
Seeps and wet spots		
Flood plain soils		
Rock outcrops		
Sinkholes		
Utilities		
Easements, etc.		
Sources of contamination		
Miscellaneous		

TABLE 6.2 *(Continued)*

SITE EVALUATION SUMMARY CHECKLIST

ITEM	STATUS	LIMITING CONDITIONS
FIELD INVESTIGATION		
Landscape Analysis		
SDA 1- Existing/proposed		
SDA 2 - Alternative		
Fill		
Cuts		
Erosion		
Upslope drainage area		
FIELD INVESTIGATION		
Soil Descriptions and Tests		
SDA 1 - Limiting zones		
SDA 1 - Permeable soil		
SDA 1 - Restrictive layer		
SDA 1 - Percolation tests		
SDA 1 - Miscellaenous		
SDA 2 - Limiting zones		
SDA 2 - Permeable soil		
SDA 2 - Restrictive layer		
SDA 2 - Percolation tests		
SDA 2 - Miscellaneous		
RECOMMENDATIONS		
SDA 1		
SDA 2		

MARYLAND DEPT. OF THE ENVIRONMENT ONSITE SEWAGE DISPOSAL SYSTEM SITE EVALUATION REPORT SUMMARY AND RECOMMENDATIONS LOT SECTION	FILE NO. MD. GRID: TAX MAP/B/P: SUBDIVISION: DATE:

RECOMMENDATIONS - SDA 1						BY:
1.Suitable	Y / N	Variance	Y / N	Variance -		
2.System Type	Trench	Y / N	Mound	Y / N	Other-	
3.Design Data	Loading Rate		gpd/sqft-		Rate(MPI)-	
	Sidewall(ft)-		Depth(ft)-		Width(ft)-	
	Spacing(ft)-		Sand(ft)-		Length(ft)-	
	Basal Area	(sq.ft.)			Other-	
	System Components					
	Tank Size		Compartments -		Location	
	Pump	Y / N	Size		Location	
	Misc.					
4.System Layout						(See sketch)
5.Total Area	3BR(sqft)-		5BR(sqft)-		Other-	
6.Additional Specifications						

RECOMMENDATIONS - SDA 2						BY:
1.Suitable	Y / N	Variance	Y / N	Variance -		
2.System Type	Trench	Y / N	Mound	Y / N	Other-	
3.Design Data	Loading Rate		gpd/sqft-		Rate(MPI)-	
	Sidewall(ft)-		Depth(ft)-		Width(ft)-	
	Spacing(ft)-		Sand(ft)-		Length(ft)-	
	Basal Area	(sq.ft.)			Other-	
	System Components					
	Tank Size		Compartments -		Location	
	Pump	Y / N	Size		Location	
	Misc.					
4.System Layout						(See sketch)
5.Total Area	3BR(sqft)-		5BR(sqft)-		Other-	
6.Additional Specifications						

FIGURE 6.1
Recommendation form.

TABLE 6.3

MAXIMUM WASTEWATER INFILTRATION RATES FOR DESIGN OF SOIL ABSORPTION SYSTEM REPAIRS WHEN PERCOLATION TEST DATA IS >30 MIN./IN.

SOIL CONDITION		TRENCH LOADING RATE (gpd/ft.^{2})[a,b,c]
A.	Is the soil texture of the entire profile 3 feet below the infiltrative surface extremely gravelly sand, gravelly coarse sand or coarser?	0.4[d]
B.	Is the soil structure of the horizon moderate or strong platy?	0.2[g]
C.	Is the soil texture of the horizon sandy clay loam, clay loam, silty clay loam, silt loam or finer, and the soil structure weak platy?	0.3[g]
D.	Is the moist soil consistence of the horizon stronger than firm or any cemented class?	NP[e,f]
E.	Is the soil texture of the horizon sandy clay, clay or silty clay of high clay content, and the soil structure massive or weak?	NP[e,f]
F.	Is the soil texture of the horizon sandy clay loam, clay loam, silty clay loam, silt or silt loam, and the soil structure massive?	0.2[g]
G.	Is the soil texture of the horizon sandy clay, clay or silty clay of low clay content, and the soil structure moderate or strong?	0.3
H.	Is the soil texture of the horizon sandy clay loam, clay loam, silty clay loam or silt loam, and the soil structure weak?	0.3
I.	Is the soil texture of the horizon sandy clay loam, clay loam or silty clay loam, and the soil structure moderate or strong?	0.5
J.	Is the soil texture of the horizon loam or sandy loam, and the soil structure massive?	0.4
K.	Is the soil texture of the horizon loam or sandy loam, and the soil structure weak?	0.5
L.	Is the soil texture of the horizon sandy loam, loam or silt loam, and the soil structure moderate or strong?	0.6
M.	Is the soil texture of the horizon very fine sand or loamy very fine sand? Or condition N below but with massive soil structure?	0.5
N.	Is the soil texture of the horizon fine sand or loamy fine sand?	0.6
O.	Is the soil texture of the horizon loamy sand, sand or coarse sand?	0.8

NOTE: If the answer to the condition is yes, the infiltrative, exposed natural soil surface for the system shall be sized using the identified soil loading factor in gallons per square foot per day **(a,b,c)**.

a. The infiltration rates may be adjusted due to crossing horizons at the proposed infiltrative surface. Where such conditions occur, a weighted average may be used to determine the infiltration rate.

b. The infiltration rates and soil conditions specified may be verified by the County or department, which may require modification of these rates, particularly where soil conditions exist that are not specifically referenced in this Table.

c. A soil description report shall be completed for each soil profile. The reported texture, structure and consistence shall be used in calculating the loading rate of the infiltrative surface.

d. Pressure distribution shall be provided except that doses shall be provided more than 4 times per day to increase retention time. If at least a 6-foot separation below the proposed system to a limiting zone is evaluated and determined, or if a sand textured blanket at least 1-foot thick is provided at the infiltrative surface, then a soil loading rate of 0.8 may be used with or without pressure distribution. Split spoon or power auger equipment may be used for evaluations at depths of more than 3 feet below the proposed system, provided such usage is noted on the soil description report.

e. NP = not permitted.

f. Soil horizons meeting conditions **d** or **e** are not permitted within 3 feet below the infiltrative surface for either seepage beds or trenches. Soil horizons meeting conditions **b**, **c** or **f** are not permitted within 3 feet below the infiltrative surface for seepage beds.

g. Pressure distribution is required.

SOURCE: Modified from Tyler et al. (1991).

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APPENDIX B: APPLICABLE STATE REGULATIONS AND GUIDELINES

REGULATIONS

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3. Code of Maryland Regulations (COMAR). Feb. 1986. Title 26. Department of the Environment. Subtitle 04. Regulation of water supply, sewage disposal and solid waste. Chapter 03. Water supply and sewerage systems in the subdivision of land in Maryland.

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GUIDELINES

1. Maryland Department of the Environment. 1992. Guidelines for on-site community systems and multiple use sewage systems with accumulative flow exceeding 5000 gallons per day.

APPENDIX C: GLOSSARY

A-horizon:	Horizon formed at or near the surface, but within the mineral soil, having properties that reflect the influence of accumulating organic matter or eluviation, alone or in combination.
adsorption:	Increased concentration of molecules or ions at a surface, including exchangeable cations and anions on soil particles.
aerobic:	(1) Having molecular oxygen as a part of the environment. (2) Growing or occurring only in the presence of molecular oxygen, such as aerobic organisms.
aggregate, soil:	Group of soil particles cohering so as to behave mechanically as a unit. Natural soil aggregates, such as granules, blocks or prisms, are called peds. Clods are aggregates produced by tillage.
alluvium:	Material, such as sand, silt or clay, deposited on land by streams.
anaerobic:	(1) Absence of molecular oxygen. (2) Growing in the absence of molecular oxygen (such as anaerobic bacteria).
aquic conditions:	Soils with aquic conditions are those which currently experience continuous or periodic saturation and reduction. The presence of these conditions is indicated by redoximorphic features and can be verified, except in artificially drained soils, by measuring saturation and reduction in soil materials.
bedrock:	Solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.
B-horizon:	Horizon immediately beneath the A-horizon characterized by a higher colloid (clay or humus) content, or by a darker or brighter color than the soil immediately above or below, the color usually being associated with the colloidal materials. The colloids may be of illuvial origin, as clay or humus; they may have been formed in place (clays including sesquioxides); or they may have been derived from a texturally layered parent material.
boulders:	Rock fragments larger than 2 feet (60 centimeters) in diameter.

bulk density, soil: Mass of dry soil per unit bulk volume. The bulk volume is determined before drying to constant weight at 105°C.

C-horizon: Horizon that normally lies beneath the B-horizon but may lie immediately beneath the A-horizon, where the only significant change caused by soil development is an increase in organic matter, which produces an A-horizon. In concept, the C-horizon is unaltered or slightly altered parent material.

capillary attraction: A liquid's movement over, or retention by, a solid surface, due to the interaction of adhesive and cohesive forces.

cation exchange: Interchange between a cation in solution and another cation on the surface of any surface-active material, such as clay or organic colloids.

cation-exchange capacity: Sum total of exchangeable cations that a soil can adsorb; sometimes called total-exchange, base-exchange capacity or cation-adsorption capacity. Expressed in milliequivalents per 100 grams of soil.

channery soil: Soil that is, by volume, more than 15 percent thin, flat fragments of sandstone, shale, slate, limestone or schist as much as 6 inches along the longest axis. A single piece is called a fragment.

clay: (1) Soil separate consisting of particles <0.002 mm in equivalent diameter. (2) Textural class in the USDA classification system.

clay film: Thin coating of oriented clay on the surface of a soil aggregate or lining pores or root channels. Also referred to as clay skins.

clay mineral: Naturally-occurring inorganic crystalline or amorphous material found in soils and other earthy deposits, the particles being predominantly <0.002 mm in diameter. Largely of secondary origin.

coarse fragments: If round, mineral or rock particles 2 millimeters to 25 centimeters (10 inches) in diameter; if flat, mineral or rock particles (flagstone) 15 to 38 centimeters (6 to 15 inches) long.

coarse-textured: Texture exhibited by sands, loamy sands.

columnar structure: Soil structural type with a vertical axis much longer than the horizontal axes and a distinctly rounded upper surface.

colluvium: Soil material, rock fragments, or both moved by creep, slide or local wash and deposited at the base of steep slopes.

complex slope: Irregular or variable slope.

concretions: Grains, pellets or nodules of various sizes, shapes, and colors consisting of concentrated compounds or cemented soil grains. The composition of most concretions is unlike that of the surrounding soil. Calcium carbonate, manganese and iron oxide are common compounds in concretions.

conductivity, hydraulic: As applied to soils, the ability of the soil to transmit water in liquid form through pores.

consistence, soil: (1) Resistance of a material to deformation or rupture. (2) The degree of cohesion or adhesion of the soil mass. Terms used for describing consistence at various soil moisture contents are:

- *loose:* noncoherent when dry or moist; does not hold together in a mass;
- *friable:* when moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump. Described as very friable and friable;
- *firm:* when moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable. Described as firm, very firm and extremely firm;
- *plastic:* when wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger. Described as slightly plastic, plastic and very plastic;
- *sticky:* when wet, adheres to other material and tends to stretch somewhat and pull apart rather than to pull free from other material. Described as slightly sticky, sticky and very sticky;
- *hard:* when dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger. Described as slightly hard, hard, very hard and extremely hard;
- *soft:* when dry, breaks into powder or individual grains under very slight pressure;

- *cemented:* hard; little affected by moistening. Described as weakly cemented, strongly cemented and indurated;

- *crumb:* soft, porous, more or less rounded ped from 1 to 5 mm in diameter; and

- *crust:* surface layer on soils, ranging in thickness from a few millimeters to perhaps as much as an inch, that is much more compact, hard, and brittle when dry than the material immediately beneath it.

denitrification: Biochemical reduction of nitrate or nitrite to gaseous molecular nitrogen or an oxide of nitrogen.

disperse: To break up compound particles, such as aggregates, into the individual component particles.

drainage class: Refers to the frequency and duration of periods of saturation or partial saturation during soil formation, as opposed to altered drainage, which is commonly the result of artificial drainage or irrigation but may be caused by the sudden deepening of channels or the blocking of drainage outlets. Seven classes of natural soil drainage are recognized and include:

- *excessively drained:* free of mottling related to wetness;

- *somewhat excessively drained:* free of mottling related to wetness.

- *well drained:* commonly medium textured and mainly free of mottling (>40 inches);

- *moderately well drained:* commonly have a slowly pervious layer within or directly below the solum, with mottling 20–40 inches;

- *somewhat poorly drained:* commonly have a slowly pervious layer, a high water table, additional water from seepage, or a combination of these. Mottling occurs 10–20 inches;

- *poorly drained:* poor drainage results from a high water table, a slowly pervious layer within the profile, seepage, or a combination of these; and

- *very poorly drained:* water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season. Unless the soil is artificially drained, most mesophytic crops cannot be grown. Very poorly drained soils are commonly level or depressed and are frequently ponded. Yet, where rainfall is high and nearly continuous, they can have moderate or high slope gradients.

effluent: Sewage, water or other liquid, partially or completely treated or in its natural state, flowing out of the reservoir, basin or treatment plant.

effective size: Size of a grain such that 10 percent of the particles by weight are smaller and 90 percent are greater.

eluviation: Movement of material in the soil in true solution or colloidal suspension from one place to another within the soil. Soil horizons that have lost material through eluviation are eluvial; those that have received material are illuvial.

erosion: Wearing away of the land surface by water, wind, ice or other geologic agents, and by such processes as gravitational creep.

evapotranspiration: Combined loss of water from a given area, and during a specified period of time, by evaporation from the soil surface and by transpiration from plants.

fine textured soil: Texture exhibited by soils having sandy clay, silty clay and clay as a part of their textured class name.

flooding: The temporary covering of the soil surface by flowing water from any source, such as streams overflowing their banks, runoff from adjacent or surrounding slopes, inflow from high tides, or any combination of sources. Shallow water standing or flowing during or shortly after rain or snow melt is excluded from the definition of flooding. Standing water (ponding) or water that forms a permanent covering is excluded from the definition. Flooding class estimates are based on interpretation of soil properties and other evidence gathered during soil survey field work. Flooding hazard is expressed by (1) frequency classes, (2) duration classes, and (3) time of year flooding occurs. Not considered here, but nevertheless important, are velocity and depth of floodwater. Frequencies used to define classes are generally estimated from evidence related to the soil and vegetation. They are expressed in wide ranges that do not indicate a high degree of accuracy. Flood frequencies that are more precise can be calculated by using a complex analyses used by engineers. The most precise evaluation of flood-prone areas for stream systems is based on hydrologic and hydraulic studies.

floodplain: Flat or nearly flat land on the floor of a river valley that is covered by water during floods.

floodway: Channel built to carry excess water from a stream.

fragipan: Loamy, brittle subsurface horizon low in porosity and content of organic matter and low or moderate in clay but high in silt or very fine sand. A fragipan appears cemented and restricts roots. When dry, it is hard or very hard and has a higher bulk density than the horizons above. When moist, it tends to rupture suddenly under pressure rather than to deform slowly.

frequently flooded, ponded, saturated: Frequency class in which flooding, ponding or saturation is likely to occur often under usual weather conditions (more than 50 percent chance in any year or more than 50 times in 100 years.)

gleyed soil: Soil that formed under poor drainage, resulting in the reduction of iron and other elements in the profile and in gray colors and mottles.

growing season: Portion of the year when soil temperatures are above biologic zero in the upper part. The following growing season months are assumed for each of the soil temperature regimes of Soil Taxonomy:

- Isohyperthermic - January–December
- Hyperthermic - February–December
- Isothermic - January–December
- Thermic - February–October
- Isomesic - January–December
- Mesic - March–October
- Frigid - May–September
- Cryic - June–August
- Pergelic - July–August

gully: Miniature valley with steep sides cut by running water and through which water ordinarily runs only after rainfall. The distinction between a gully and a rill is one of depth. A gully generally is an obstacle to farm machinery and is too deep to be obliterated by ordinary tillage; a rill is of lesser depth and can be smoothed over by ordinary tillage.

hardpan: Hardened soil layer, in the lower A- or in the B-horizon, caused by cementation of soil particles with organic matter or with materials such as silica, sesquioxides or calcium carbonate. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not slake in water.

heavy soil: (Obsolete in scientific use.) Soil with a high content of the fine separates, particularly clay, or one with a high drawbar pull and hence difficult to cultivate.

hydraulic conductivity: (See "conductivity, hydraulic.")

humus: Well decomposed, more or less stable part of the organic matter in mineral soils.

illuviation: Movement of soil material from one horizon to another in the soil profile. Generally, material is removed from an upper horizon and deposited in a lower horizon.

impervious: Resistant to penetration by fluids or by roots.

infiltration: Downward entry of water into the immediate surface of soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.

ion: Charged atom, molecule or radical, the migration of which affects the transport of electricity through an electrolyte or, to a certain extent, through a gas. An atom or molecule that has lost or gained one or more electrons; by such ionization the atom becomes electrically charged. An example is the alpha particle.

ion exchange: Chemical process involving reversible interchange of ions between a liquid and a solid but no radical change in structure of the solid.

leaching: Removal of materials in solution from the soil.

limiting zone: Any zone, horizon, layer or characteristic of the soil that will limit the capability of the soil to transmit, absorb or renovate effluent and includes:

- *seasonal high water table:* perched or apparent, determined by direct piezometer measurement during the wet season and representative of maximum height of water for normal or near normal precipitation. Estimated by depth in soil of wetness-related mottles with ≤ 2 chroma (i.e., aquic conditions and associated redoximorphic features as defined by USDA–SCS, 1992);

- *fractured rock:* rock with open joints, fractures or solution channels. Soil and rock fragments >50 percent by volume with insufficient soil to fill the voids between fragments and with percolation rates <2 minutes per inch, or saturated hydraulic conductivity estimates equal to or greater than 14 inches per hour; and

- *restrictive layer:* consolidated rock, fragipans, ironstone layers, substratum layers or soil conditions that effectively limit downward movement of water. Includes horizons and layers with moderate or strong platy structure, moist consistence stronger than firm or cemented, or soil material with textures of sandy clay, clay or silty clay with weak or massive soil structure, or horizons or layers with saturated hydraulic conductivity estimates less than 0.14 inches per hour.

long duration: Duration class in which inundation for a single event ranges from 7 days to 1 month.

mapping unit: Soil landscape unit or combination of soils delineated on a map and, where possible, named to show the taxonomic unit or units included. Principally, mapping units on maps of soils depict soil phases, associations, complexes or miscellaneous land types.

medium texture: Texture exhibited by very fine sandy loams, loams, silt loams and silts.

mineral soil: Soil consisting predominantly of, and having its properties determined by, mineral matter. Usually contains <20 percent organic matter, but may contain an organic surface layer up to 30 cm thick.

mineralization: Conversion of an element from an organic form to an inorganic state as a result of microbial decomposition.

mineralogy, soil: In practical use, the kinds and proportions of minerals present in soil.

moderately coarse-textured soil: Sandy loam and fine sandy loam.

moderately fine-textured soil: Clay loam, sandy clay and silty clay loam.

montmorillonite: Aluminosilicate clay mineral with a 2:1 expanding structure; that is, with two silicon tetrahedral layers enclosing an aluminum octahedral layer. Considerable expansion may be caused by water moving between silica layers of contiguous units.

mottling: Spots or blotches of different color or shades of color interspersed with the dominant color.

mottling, soil: Descriptive terms are as follows:

1) abundance: few, common and many;

2) size: fine, medium and coarse; and

3) contrast: faint, distinct and prominent.

The size measurements are of the diameter along the greatest dimension. Fine indicates less than 5 millimeters (about 0.2 inch); medium, from 5 to 15 millimeters (about 0.2 to 0.6 inch); and coarse, more than 15 millimeters (about 0.6 inch).

munsell notation: Designation of color by degrees of the three simple variables: hue, value and chroma. For example, a notation of 10 YR 6/4 is a color of 10 YR hue, value of 6 and chroma of 4.

nitrification: Biochemical oxidation of ammonium to nitrate.

organic nitrogen: Nitrogen combined in organic molecules such as proteins, amino acids.

organic soil: Soil which contains a high percentage (>15 percent or 20 percent) of organic matter throughout the solum.

parent material: Unconsolidated organic and mineral material in which soil forms.

particle size: Effective diameter of a particle usually measured by sedimentation or sieving.

particle-size distribution: Amounts of the various soil separates in a soil sample, usually expressed as weight percentage.

pathogenic: Causing disease. "Pathogenic" is also used to designate microbes which commonly cause infectious diseases, as opposed to those which do so uncommonly or never.

ped: Unit of soil structure such as an aggregate, crumb, prism, block or granule, formed by natural processes (in contrast with a clod, which is formed artificially).

pedon: Smallest volume (soil body) which displays the normal range of variation in properties of a soil. Where properties such as horizon thickness vary little along a lateral dimension, the pedon may occupy an area of a square yard or less. Where such a property varies substantially along a lateral dimension, a large pedon several square yards in area may be required to show the full range in variation.

percolation:	Flow or trickling of a liquid downward through a porous or filtering medi The liquid may or may not fill the pores of the medium.
permeability, soil:	Ease with which gases, liquids or plant roots penetrate or pass through soil.
pH:	Term used to describe the hydrogen-ion activity of a system.
phase, soil:	Subdivision of a soil series based on features that affect its use and management. For example, slope, stoniness and thickness.
plastic soil:	Soil capable of being molded or deformed continuously and permanently, by relatively moderate pressure, into various shapes. (See "consistence.")
platy structure:	Soil aggregates that are developed predominantly along the horizontal axes; laminated; flaky.
ponded:	Condition in which water stands in a closed depression. The water is removed only by percolation, evaporation or transpiration.
ponding:	Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by percolation or evapotranspiration.
profile, soil:	Vertical section of the soil extending through all its horizons and into t parent material.
redoximorphic features:	Features associated with wetness resulting from the reduction and oxidation of iron and manganese compounds in the soil after saturation with water and desaturation, respectively. Movement of iron and manganese as a result of redox processes in a soil may result in redoximorphic features that are defined as follows:

- *redox concentrations:* zones of apparent accumulation of Fe-Mn oxides, including:

  (1) nodules and concretions, i.e., firm, irregularly shaped bodies with diffuse boundaries if formed *in situ*;

  (2) masses, i.e., soft bodies of variable shapes within the matrix; and

  (3) pore linings, i.e., zones of accumulation along pores which may be either coatings on pore surfaces or impregnations from the matrix adjacent to the pores;

- *redox depletions:* zones of low chroma (2 or less) where either Fe-Mn oxides alone or both Fe-Mn oxides and clay have been stripped out, including:

  (1) iron depletions, i.e., zones which contain low amounts of Fe and Mn oxides but have a clay content similar to that of the adjacent matrix; and

  (2) clay depletions, i.e., zones which contain low amounts of Fe, Mn and clay.

- *reduced matrix:* soil matrix which has low chroma *in situ*, but whose hue or chroma increases within 30 minutes after the soil material has been exposed to air.

In soils that have no visible redoximorphic features, a reaction to an ox, ox-dipyridyl solution satisfies the requirement for redoximorphic features.

reduction, soil: Degree of reduction in a soil can be characterized by the direct measurement of redox potentials. Direct measurements should take into account chemical equilibria as expressed by stability diagrams in standard soil textbooks. Reduction and oxidation processes are also a function of soil pH. Accurate measurements of the degree of reduction existing in a soil are difficult to obtain. A simple field test is available to determine if reduced iron ions are present. A freshly broken surface of a field-wet soil sample is treated with ox, ox-dipyridy in neutral, 1-normal ammonium-acetate solution. The appearance of a strong red color on the freshly broken surface indicates the presence of reduced iron ions.

relief: Elevations or inequalities of a land surface, considered collectively.

residuum (residual material): Unconsolidated, weathered or partly weathered mineral material that soil accumulated as consolidated rock disintegrated in place.

rill: Steep-sided channel resulting from accelerated erosion. A rill is generally a few inches deep and not wide enough to be an obstacle to farm machinery.

rock fragments: Rock or mineral fragments having a diameter of 2 millimeters or more; for example, pebbles, cobbles, stones and boulders. (See "coarse fragments.")

root zone: Part of the soil that can be penetrated by plant roots.

runoff: Precipitation discharged into stream channels from an area. The water that flows off the surface of the land without sinking into the soil is called "surface runoff." Water that enters the soil before reaching surface streams is called "groundwater runoff" or "seepage flow from ground water."

saprolite: Unconsolidated residual material underlying the soil and grading to hard bedrock below.

saturation: Characterized by zero or positive pressure in the soil–water and can generally be determined by observing free water in an unlined auger hole. Problems may arise in clayey soils with peds where an unlined auger hole may fill with water flowing along faces of peds while the soil matrix remains unsaturated (bypass flow). Such free water may incorrectly suggest the presence of a water table, while the actual water table occurs at greater depth. Use of the well-sealed piezometers with small slits (0.01 inch) or fast reacting tensiometers are recommended for measuring saturation.

The duration of saturation required for creating aquic conditions is variable, depending on the soil environment, and is not specified.

Three types of saturation are defined. However, for the purposes of on-site sewage disposal the following two are recognized:

- *endosaturation:* the soil is saturated with water in all layers from the upper boundary of saturation to a depth of 78 inches (200 cm) or more from the mineral soil surface; and

- *episaturation:* the soil is saturated with water in one or more layers within 78 inches (200 cm) of the mineral soil surface and also has one or more unsaturated layers, with an upper boundary above 78 inches (200 cm depth), below the saturated layer. The zone of saturation, i.e., the water table, is perched on top of a relatively impermeable layer.

silt: (1) A soil separate consisting of particles between 0.05 and 0.002 mm in diameter. (2) A soil textural class in the USDA classification system.

single-grained: A nonstructural state normally observed in soils containing a preponderance of large particles, such as sand. Because of a lack of cohesion, the sand grains tend not to assemble in aggregate form.

sinkhole: A depression in the landscape where limestone has been dissolved.

slope: Inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100.

Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

soil:	A natural, three-dimensional body at the earth's surface. It is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.
soil horizon:	A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically-related layers in physical, chemical and biological properties or characteristics such as color, structure, texture, consistence, pH, etc.
soil map:	A map showing the distribution of soil types or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface.
soil morphology:	The physical constitution, particularly the structural properties, of a soil profile as exhibited by the kinds, thickness and arrangement of the horizons in the profile, and by the texture, structure, consistence and porosity of each horizon.
soil separates:	Groups of mineral particles less than 2 mm in equivalent diameter and separated on the basis of a range in size. The principal separates are sand, silt and clay.
soil series:	The basic unit of soil classification, consisting of soils which are essentially alike in all major profile characteristics, although the texture of the A-horizon may vary somewhat. (See "soil type.")
soil structure:	The combination or arrangement of individual soil particles into definable aggregates, or peds, which are characterized and classified on the basis of size, shape and degree of distinctness.
soil suction:	A measure of the force of water retention in unsaturated soil. Soil suction is equal to a force per unit area that must be exceeded by an externally applied suction to initiate water flow from the soil. Soil suction is expressed in standard pressure terms.
soil survey:	The systematic examination, description, classification and mapping of soils in an area.
soil texture:	The relative proportions of sand, silt and clay in a mass of soil.

soil type: (surface texture phase) In mapping soils, a subdivision of a soil series based on differences in the texture of the A-horizon.

soil water: A general term emphasizing the physical rather than the chemical properties and behavior of the soil solution.

solum: The upper part of a soil profile, above the C-horizon, in which the processes of soil formation are active. The solum in soil consists of the A- and B-horizons. Generally, the characteristics of the material in these horizons are unlike those of the underlying material. The living roots and plant and animal activities are largely confined to the solum.

stones: Rock fragments 10 to 24 inches (25cm to 60cm) in diameter.

structure, soil: The principal forms of soil structure are platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular) and granular. Structureless soils are either single grained (each grain by itself, as in dune sand) or massive (the particles adhering without any regular cleavage, as in many hardpans).

subsoil: In general concept, that part of the soil below the depth of plowing.

substratum: The part of the soil below the solum.

tensiometer: A device for measuring the negative hydraulic pressure (or tension) of water in soil *in situ*; a porous, permeable ceramic cup connected through a tube to a manometer or vacuum gauge.

tension, soil water: The expression, in positive terms, of the negative hydraulic pressure of soil water.

textural class, soil: Soils grouped on the basis of a specified range in texture. In the United States, twelve textural classes are recognized in the USDA soil textural system.

texture: (See "texture, soil.")

texture, soil: The basic textural classes, in order of increasing proportion of fine particles, are: sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay and clay. The sand, loamy sand and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

tight soil: A compact, relatively impervious soil (or subsoil), which may or may not be plastic.

Total Kjeldahl Nitrogen (TKN): An analytical method for determining total organic nitrogen and ammonia.

topsoil: (1) The layer of soil moved in cultivation. (2) The A-horizon. (3) The Al-horizon. (4) Presumably fertile soil material used to topdress roadbanks, gardens and lawns.

unsaturated flow: The movement of water in a soil which is not filled to capacity with water.

very long duration: A duration class in which inundation for a single event is greater than one month.

water table: That level in saturated soil where the hydraulic pressure is zero.

water table, perched: The water table of a discontinuous saturated zone in a soil.

weathering: All physical and chemical changes produced in rocks or other deposits at or near the earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

Glossary:

The definitions contained in this glossary are not necessarily endorsed by MDE or MCET nor are they to be viewed as language for regulatory purposes. The definitions were taken primarily from the list of references provided below. Some adaptation of the definitions from these references is included in this glossary, and users of this glossary should always supplement their understanding by additional reading and study.

1. U.S. Environmental Protection Agency. 1980. Design manual for on-site wastewater treatment and disposal. EPA 625/1-80-012. U.S. EPA Center for Environmental Research Information, Cincinnati, OH.

2. Custer, B.H. 1985. Soil Survey of Lancaster County, Pennsylvania. USDA–SCS. U.S. Gov. Print. Office, Washington, DC.

3. Pennsylvania Department of Environmental Resources. 1985. Technical manual for sewage enforcement officers. 5th Ed. Harrisburg, PA.

4. U.S. Environmental Protection Agency. 1987. Guidelines for delineation of wellhead protection areas. U.S. EPA Office of Groundwater Protection, Washington, DC.

APPENDIX D: SITE EVALUATION FORMS AND STANDARD ABBREVIATIONS OF TERMS

MARYLAND DEPT. OF THE ENVIRONMENT ONSITE SEWAGE DISPOSAL PERMIT SITE EVALUATION REPORT APPLICATION FORM				FILE NO. MD. GRID: COUNTY: TAX MAP/B/P: SUBDIVISION:			
OWNER NAME				APPLICANT			
ADDRESS				ADDRESS			
TELEPHONE				TELEPHONE			
PROPERTY DATA							
PROPERTY				DIRECTIONS			
ADDRESS							
TAX MAP NO.		BLOCK		PARCEL NO.		PARCEL SIZE	
SUBDIVISION				SECTION		TAX ACCT. NO.	
LOT NO.		LOT SIZE					
EXISTING FACILITIES							
SITE TESTS	Y / N	FILE NAME –					
ONSITE WELL	Y / N	DESCRIPTION–		DEPTH (ft)		PUBLIC WATER	Y / N
RESIDENCE	Y / N	OCCUPIED	Y / N	BEDROOMS		TOTAL SQ.FT.	
PLUMBING	Y / N	DISPOSAL SYSTEM TYPE–					
COMMERCIAL	Y / N	EXISTING USE–					
PROBLEMS	Y / N	DESCRIPTION –					
VEGETATION AT SITE		WOODED	Y / N	OPEN	Y / N	CROPS	Y / N
PROPOSED FACILITIES							
CONSTRUCTION TYPE		NEW	Y / N	ADDITIONS	Y / N	REPAIR	Y / N
ONSITE WELL	Y / N	DESCRIPTION –		DEPTH(ft)		PUBLIC WATER	Y / N
RESIDENCE	Y / N	PERSONS		BEDROOMS		TOTAL SQ.FT.	
COMMERCIAL	Y / N	PROPOSED USE–					
SYSTEM TYPE	TRENCH	Y / N	MOUND	Y / N	OTHER –		
LOW FLOW	TOILETS	Y / N	SHOWERS	Y / N	OTHER –		
SITE PLAN		Submit Site Development Plan According To Attached Instructions					

INFORMATION ABOVE IS TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE.

SIGNATURE ______________________________ OWNER / APPLICANT ______ DATE

FOR OFFICIAL DEPARTMENT USE ONLY. DO NOT WRITE BELOW THIS LINE.

FEE RECEIPT # DATE TOTAL PAID $

APPLICATION REVIEW					
SITE PLAN ATTACHED	Y / N	DATE		DATE COMPLETE	
COUNTY W&S PLAN	Y / N	PROHIBITED ZONE		Y / N	
BAY CRITICAL AREA	Y / N	WHP AREA	Y / N	EXISTING RECORDS	Y / N
SOIL MAPPING UNITS				FLOODPLAIN SOILS	Y / N
WET SEASON TESTS	Y / N	GPR AREA		REVIEWED BY:	
RECOMMENDATION	APPLICATION APPROVED			Y / N	DATE

MARYLAND DEPT. OF THE ENVIRONMENT
ONSITE SEWAGE DISPOSAL PERMIT
SITE EVALUATION REPORT
SOIL PROFILE DESCRIPTION

LOT SECTION

FILE NO.
MD. GRID:
COUNTY:
TAX MAP/B/P:
SUBDIVISION:
DATE:

DEPTH		TEXTURE	MATRIX COLOR	MOTTLES DESCRIPTION	STRUCTURE	CONSISTENCE	REMARKS (R.F.%,Moisture)
HOLE						BY:	
Slope%–		EL.(ft)–		Chroma 2–	Least Permeable Layers–		
Landscape Position–				Water BLS–	Limiting Zones–		
Additional Remarks–							
HOLE						BY:	
Slope%–		EL.(ft)–		Chroma 2–	Least Permeable Layers–		
Landscape Position–				Water BLS–	Limiting Zones–		
Additional Remarks–							

MARYLAND DEPT. OF THE ENVIRONMENT
ONSITE SEWAGE DISPOSAL SYSTEM
SITE EVALUATION REPORT
SOIL PROFILE DESCRIPTION

LOT SECTION

FILE NO.
MD. GRID:
TAX MAP/B/P:
SUBDIVISION:
DATE:
BY:

DEPTH		TEXTURE	MATRIX COLOR	MOTTLES DESCRIPTION		STRUCTURE	CONSISTENCE	%ROCK BY VOL.	REMARKS (Caving,moisture,etc.)
HOLE									

Slope%– EL.(ft)– Chroma 2– Least Permeable Layers–
Landscape Position– Water BLS– Limiting Zones–
Additional Remarks–

MARYLAND DEPT. OF THE ENVIRONMENT
ONSITE SEWAGE DISPOSAL PERMIT
SITE EVALUATION REPORT

PERCOLATION TEST DATA

FILE NO.
MD GRID:
COUNTY:
TAX MAP/B/P:
SUBDIVISION:

LOT SECTION

METHOD				BY:		
DATE		SOIL –		WEATHER:		
DEPTH		HOLE DIA.(in.)		CONV. FACTOR		
TEST NO.	ELAPSED TIME	TIME INTERVAL (min.)	WATER LEVEL (in.)	DROP IN WATER LEVEL (in.)	RATE (min/in.)	REMARKS
				TEST RATE		

METHOD				BY:		
DATE		SOIL –		WEATHER:		
DEPTH		HOLE DIA.(in.)		CONV. FACTOR		
TEST NO.	ELAPSED TIME	TIME INTERVAL (min.)	WATER LEVEL (in.)	DROP IN WATER LEVEL (in.)	RATE (min/in.)	REMARKS
				TEST RATE		

METHOD				BY:		
DATE		SOIL –		WEATHER:		
DEPTH		HOLE DIA.(in.)		CONV. FACTOR		
TEST NO.	ELAPSED TIME	TIME INTERVAL (min.)	WATER LEVEL (in.)	DROP IN WATER LEVEL (in.)	RATE (min/in.)	REMARKS
				TEST RATE		
				AVE.RATE		

MARYLAND DEPT. OF THE ENVIRONMENT ONSITE SEWAGE DISPOSAL PERMIT SITE EVALUATION REPORT WATER LEVEL MEASUREMENTS	FILE NO. MD. GRID: COUNTY: TAX MAP/B/P: SUBDIVISION: DATE:

Well No.	Water Level Below MP (ft.)	Casing Stickup (ft.)	Water Level Below Surface (ft.)	MP Elevation (MSL ft.)	Water Level Elevation (MSL ft.)	Additional Notes

MARYLAND DEPT. OF THE ENVIRONMENT ONSITE SEWAGE DISPOSAL PERMIT SITE EVALUATION REPORT WATER LEVEL MEASUREMENTS SUMMARY	FILE NO. MD. GRID: COUNTY: TAX MAP/B/P: SUBDIVISION:

WELL NO.						
Stickup(ft.)						
Elev(ft.MSL)						
Location						

Date	Water Level BLS (ft.)	Water Level BLS (ft.)	Water Level BLS (ft.)	Water Level BLS (ft.)	Water Level BLS (ft.)	Water Level BLS (ft.)
AVERAGE						

MARYLAND DEPT. OF THE ENVIRONMENT ONSITE SEWAGE DISPOSAL SYSTEM SITE EVALUATION REPORT SUMMARY AND RECOMMENDATIONS LOT SECTION	FILE NO. MD. GRID: TAX MAP/B/P: SUBDIVISION: DATE:

RECOMMENDATIONS – SDA 1						BY:
1.Suitable	Y / N	Variance	Y / N	Variance –		
2.System Type	Trench	Y / N	Mound	Y / N	Other–	
3.Design Data	Loading Rate		gpd/sqft–		Rate(MPI)–	
	Sidewall(ft)–		Depth(ft)–		Width(ft)–	
	Spacing(ft)–		Sand(ft)–		Length(ft)–	
	Basal Area	(sq.ft.)			Other–	
	System Components					
	Tank Size		Compartments –		Location	
	Pump	Y / N	Size		Location	
	Misc.					
4.System Layout						(See sketch)
5.Total Area	3BR(sqft)–		5BR(sqft)–		Other–	
6.Additional Specifications						

RECOMMENDATIONS – SDA 2						BY:
1.Suitable	Y / N	Variance	Y / N	Variance –		
2.System Type	Trench	Y / N	Mound	Y / N	Other–	
3.Design Data	Loading Rate		gpd/sqft–		Rate(MPI)–	
	Sidewall(ft)–		Depth(ft)–		Width(ft)–	
	Spacing(ft)–		Sand(ft)–		Length(ft)–	
	Basal Area	(sq.ft.)			Other–	
	System Components					
	Tank Size		Compartments –		Location	
	Pump	Y / N	Size		Location	
	Misc.					
4.System Layout						(See sketch)
5.Total Area	3BR(sqft)–		5BR(sqft)–		Other–	
6.Additional Specifications						

SOIL PROFILE DESCRIPTION
STANDARD ABBREVIATIONS OF TERMS

TEXTURE MODIFIERS					
BY	Bouldery	CNX	Extremely channery	GRX	Extremely gravelly
BYV	Very bouldery	FL	Flaggy	MK	Mucky
BYX	Extremely bouldery	FLV	Very flaggy	PT	Peaty
CB	Cobbly	FLX	Extremely flaggy	RB	Rubbly
CBA	Angular cobbly	GR	Gravelly	SR	Stratified
CBV	Very cobbly	GRC	Coarse gravelly	ST	Stony
CBX	Extremely cobbly	GRF	Fine gravelly	STV	Very stony
CN	Channery	GRV	Very gravelly	STX	Extremely stony
CNV	Very channery				

TEXTURE TERMS					
COS	Coarse sand	LVFS	Loamy very fine sand	SI	Silt
S	Sand	COSL	Coarse sandy loam	SCL	Sandy clay loam
FS	Fine sand	SL	Sandy loam	CL	Clay loam
VFS	Very fine sand	FSL	Fine sandy loam	SICL	Silty clay loam
LCOS	Loamy coarse sand	VFSL	Very fine sandy loam	SC	Sandy clay
LS	Loamy sand	L	Loam	SIC	Silty clay
LFS	Loamy fine sand	SIL	Silt loam	C	Clay

TERMS USED IN LIEU OF TEXTURE					
CEM	Cemented	GYP	Gypsiferous material	PEAT	Peat
CIND	Cinders	HM	Hemic material	SG	Sand and gravel
DE	Diatomaceous earth	ICE	Ice or frozen soil	SP	Sapric material
FB	Fibric material	IND	Indurated	UWB	Unweathered bedrock
FRAG	Fragmented material	MARL	Marl	VAR	Variable
G	Gravel	MPT	Mucky-peat	WB	Weathered bedrock
		MUCK	Muck		

APPENDIX E:
FLOODPLAIN SOILS IN MARYLAND

FLOODPLAIN SOILS AND LAND AREAS THAT FLOOD FREQUENTLY		
Alluvial Land	Congavee	Lindside
Atkin	Dunning	Melvin
Augusta	Elkins	Nanticoke
Axis	Fluvents	Ochlockanee
Beaches	Fluvaquents	Osier
Bermudian	Guthrie	Philo
Bestpitch	Hatboro	Pope
Bibb	Honga	Puckum
Bowmansville	Huntington	Rowland
Chewacla	Iuka	Rutledge
Chicone	Johnston	Sunken
Codorous	Kingsland	Tidal Marshes
Comus	Largent	Warners

SOURCE: USDA–SCS *Soil Surveys in Maryland* and USDA–SCS Soils Form 5.

APPENDIX F: WASTEWATER FLOWS FOR USE IN DESIGNING ON-SITE SEWAGE SYSTEMS

Establishment	GPD Per Unit*
AIRPORT	
per employee	15
per passenger	5
(add for food service facility)	
ANIMAL SHELTER/KENNEL	
per run	25
add per employee/shift	15
BEAUTY/BARBER SHOP	
per station	350
BOWLING ALLEY	
per employee	15
per lane, no bar/food	75
per lane, bar only	125
per lane, bar & food	200
CHURCH–ASSEMBLY HALL	
per seat	3
(add for food service)	
COLLEGE, COMMUNITY	
per employee & student	15
(add for food service)	

Establishment	GPD Per Unit*
COMMERCIAL ESTABLISHMENT (Per sq. ft.) If no category is shown and where shops and uses are clustered and uses change (not necessarily for use when only one shop or store's predetermined use is known). See individual categories when single use buildings are being considered.	
Office Buildings	.09
Medical Office Building	.62
Warehouses	.03
Retail Stores	.05
Supermarkets	.20
Drug Stores	.13
Beauty Salons	.35
Barber Shops	.20
Dept. Store w/Lunch Counter	.08
Dept. Store w/o Lunch Counter	.04
Banks	.04
Service Station	.18
Laundries & Cleaners	.31
Laundromats	3.68
Car Wash w/o Recirc. Equip.	4.90
Hotels	.25
Motels	.23
Dry Goods Stores	.05
Shopping Centers	.18

*Flows are considered maximum daily flows in accordance with COMAR 26.04.02.05.M.

Establishment	GPD Per Unit*
COUNTRY CLUB	
per resident member/per room	100
per non-resident member	25
DANCE HALL	
per seat	5
(add for food service)	
DENTIST OFFICE	
per chair	450
DOCTOR'S OFFICE	
see Medical Office per sq. ft.	
DRIVE-IN THEATER	
per car space	5
FACTORY (Manufacturing Plant)	
per employee/per shift	15
add for showers per employee	10
FAIRGROUND	
per person	5
GOLF COURSE (Public)	
per 18 holes	5000
per 9 holes	2500
HOME FOR THE AGED	
per bed space	100
HOSPITAL	
per bed	350
INSTITUTION–NURSING HOME	
per bed	200
LAUNDRY–COIN OPERATED	
per machine/per 24 hours	400
MARINA	
per slip <25 ft.	10
per slip ≥25 ft. to ≤35 ft.	25
per slip >35 ft.	75
boatels (per slip/space) divide by 3	15
pump-out station per slip (storage volume only)	35
MOBILE HOME PARK	
per lot, minimum	300
MOTEL–HOTEL	
per unit, no food, no kitchen	125
per unit, with food/kitchen/efficiency	200
OFFICE	
per employee/8 hr. shift	15
PARK	
per person w/toilets provided	10
add for showers	10
visitor center per parking space	45
PRISON/JAIL	
per bed space	125
per employee/shift	15
RESIDENTIAL (APARTMENT/CONDO)	
per bedroom	150
rooming/boarding per bed	75

* Flows are considered maximum daily flows in accordance with COMAR 26.04.02.05.M.

Establishment	GPD Per Unit*
RESTAURANT/FOOD SERVICE	
24-Hour Operation or Fast Food	
per seat	75
Interstate/Major Highway	
per seat	150
12-Hour Operation	
per seat	50
Bar/Tavern/Pub	
per seat	25
Banquet Room	
per seat (assoc. with restaurant)	5
per seat, exclusively banquet facility	25
SCHOOL (per student)	
no food or showers	15
add for food	5
add for showers	10
boarding	100
SERVICE STATION	
State highway rest area (mini station)	2000
Federal interstate (no on-site disposal allowed)	
SPA/SAUNA/JACUZZI	
20% of volume	
SWIMMING POOL	
per swimmer	10
per employee	15
THEATER–ARENA	
per seat, no food	5
(add for food service)	

Establishment	GPD Per Unit*
THEATER–DINNER	
per seat	20
SPORTS ARENA	
per seat	5
(add for food service)	
TRAVEL TRAILER PARK/CAMP	
per space	150
per space with sewer/service building	175
children's camp p/p	50
labor camp p/p	50
luxury camp p/p	100
p/p day camp (no meals)	15

GPD = gallons per day

p/p = per person

p/c = per customer

* Flows are considered maximum daily flows in accordance with COMAR 26.04.02.05.M.

APPENDIX G: ON-SITE SEWAGE DISPOSAL SYSTEMS USED IN MARYLAND

1. **Shallow Trench** – This system consists of a single or double-compartment septic tank, distribution box, gravity flow piping distribution system and shallow gravel fill trenches. Gravel fill commonly 0.5 to 1.0 feet below distribution piping, with system design based on bottom area only.

2. **Deep Trench** – This system consists of a single or double-compartment septic tank, distribution box, gravity flow piping distribution system and deep gravel fill trenches. Gravel fill typically ranges from 3 to 12 feet but may extend deeper for some systems. System design is based on a formula for using both sidewall and bottom area.

3. **Sand Mound** – This system consists of a double-compartment septic tank, pump, pumping chamber and an absorption bed elevated above the natural soil surface in a suitable sand fill. Septic tank effluent is pumped into the bed through a pressure distribution network. Treatment occurs as effluent moves downward through the sand fill and into the underlying soil.

4. **Elevated Bed** – This system consists of double-compartment septic tank, pump, pumping chamber and an absorption bed placed at grade, elevated above the soil surface. This system is similar to the sand mound system, except no sand is required. This is also referred to as the Wisconsin At-Grade System.

5. **Sand-Lined Trench** – This system consists of a double-compartment septic tank and soil absorption trenches. The trenches are constructed to discharge directly to non-potable groundwater but are backfilled with sand instead of gravel. The trenches may be elevated above the original land surface in an impermeable fill in order to obtain adequate hydraulic head for performance when the water table is high. This system has been used in Maryland to overcome site limitations of nearly impermeable soils with high water tables overlying sandy substratum materials. This system can only be used in certain areas of the oastal Plain designated in local Groundwater Protection Reports (GPR).

6. **Bermed Infiltration Pond** – This system consists of a septic tank, pump, pumping chamber and bermed infiltration pond. A bermed infiltration pond is an excavation approximately eight to ten feet deep with no less than 10,000 square feet in surface area. The excavation exposes a water-bearing substratum overlain by an impermeable soil. Part of the excavated material is placed around the pond perimeter to form a berm. The water from the sandy substratum rises and falls in the pond in accordance with seasonal fluctuations in the water table. Septic tank effluent is discharged near the bottom of the pond for disposal. The biological organisms in the pond provide additional treatment and the water moves into near surface non-potable

biological organisms in the pond provide additional treatment and the water moves into near surface non-potable groundwater surrounding the pond. This system can only be used in certain areas of the Coastal Plain designated in local Groundwater Protection Reports (GPR).

APPENDIX H:
SITE SCREEING CRITERIA FOR ON-SITE SEWAGE DISPOSAL SYSTEMS IN MARYLAND

TABLE H.1

MARYLAND DEPARTMENT OF THE ENVIRONMENT
ON-SITE SEWAGE DISPOSAL SYSTEM
SITE SCREENING CRITERIA

DISPOSAL SYSTEM	SLOPE PERCENT			DEPTH TO SEASONAL HIGH WATER (ft.)				DEPTH TO BEDROCK OR PAN (In.)					SOIL TEXTURE GROUP			
	<15	15–25	>25	<1.5	1.5–2.0	2.0–6.0	>6.0	<24	24–36	36–48	48–60	>60	1	2	3	4
Trench	S	S	U	U	U	U-M2	S	U-M1	U-M1	U-M1	U-M2	S-S1	M3	S-M3	M-U	U
Elevated Bed	S-M	U	U	U	U	S1	S	U	U	M-S	S	S	M3	S-M3	S-M	U
Sand Mound	S-M	U	U	U	U-S1	S	S	U	M-S	S	S	S	S	S	S	M-U
Sand-Lined Trench	S1	S1	U	U	M-S1	S1	S1	U	U	U	U	S1	S1	S1-M	U	U
Bermed Pond	S1	U	U	S1	S1	S1-M	U	U	U	U	U	M-S1	S1	S1-M	U	U

NOTES: Soil Texture Group—at proposed system depth for trench and pond systems or limiting zone in upper 24 to 36 inches for sand mound and elevated bed systems.

Group 1 – gs, s, ls and coarser.
Group 2 – vfs, fs, lvfs, lfs, sl, l.
Group 3 – scl, sil, cl, sicl.
Group 4 – sc, sic, c.

S Indicates suitable characteristic for system.
S1 Dependent on county Groundwater Protection Report (GPR) and variances to 4 ft. treatment zone.
M Indicates marginal characteristic for system.
M1 Deep trench systems may be suitable if minor perched water body exists above pan and soil textures are suitable below the pan. Deep trench systems not suitable if limitation applies to bedrock.
M2 Shallow trench systems with fill cap may be suitable.
M3 Pressure distribution with doses >4 times per day and/or sand fill at least 1 ft. thick may be required.
U Indicates unsuitable characteristic for system.

TABLE H.2

SITE SCREENING EXAMPLE FOR SOIL MAPPING UNIT SaA

DISPOSAL SYSTEM	SLOPE PERCENT	DEPTH TO WATER (ft.)		DEPTH TO BEDROCK OR PAN (in.)	SOIL TEXTURE GROUP	
	<15	2.0–6.0	>6.0	>60	2	3
Trench	S	U-M2	S	S	S	S-M
Elevated Bed	S-M	S1	S	S	S	S-M
Sand Mound	S-M	S	S	S	S	S
Sand-Lined Trench	S1	S1	S1	S1	S1-M	U
Bermed Pond	S1	S1-M	U	M-S1	S1-M	U

NOTES: Soil Texture Group — at proposed system depth for trench and pond systems or least permeable horizon in upper 24 inches for sand mound and elevated bed systems.

Group 1 - gs, s, ls and coarser
Group 2 – vfs, fs, lvfs, lfs, sl, l
Group 3 – scl, sil, cl, sicl
Group 4 – sc, sic, c

S Indicates suitable characteristic for system.
S1 Dependent on county Groundwater Protection Report (GPR) and variances to 4 ft. treatment zone.
M Indicates marginal characteristic for system.
M1 Deep trench systems may be suitable if minor perched water body exists above pan and soil textures are suitable below the pan. Deep trench systems not suitable if limitation applies to bedrock.
M2 Shallow trench systems with fill cap may be suitable.
M3 Pressure distribution with doses >4 times per day and/or sand fill at least 1 ft. thick may be required.
U Indicates unsuitable characteristic for system.

APPENDIX I: STANDARD FALLING HEAD PERCOLATION TEST METHOD

MARYLAND DEPARTMENT OF THE ENVIRONMENT STANDARD FALLING HEAD PERCOLATION TEST METHOD

DESCRIPTION

A falling head percolation test measures the time required for a unit depth of clear water to infiltrate into the soil from a standard size uncased hole. Tests should be conducted only after soil descriptions, limiting zones and water level data indicate that required treatment zones are present and that the soils may be suitable. Representative tests are conducted at depths proposed for system infiltration surfaces and can be used to rank the relative permeabilities of different soil horizons and substratum layers.

The results of the percolation tests are interpreted empirically to confirm soil suitability and select appropriate wastewater hydraulic loading rates for system design. The test, as currently conducted, does not provide an accurate measure of saturated hydraulic conductivity and the results can be highly variable within a site.

MATERIALS AND EQUIPMENT

1) Posthole digger and round point shovel
2) Pointing trowel
3) Minimum 5 gallons of clear water per test
4) Coarse sand or pea gravel
5) Tape measure, folding rule or percolation test stick with nails
6) Watch
7) Mirror, reflector or flashlight
8) Data forms
9) Auger with 3 to 20 inch diameter bucket and extensions

LOCATION AND DEPTH OF TESTS

Information from the soil profile descriptions is used to select representative locations and depths for testing. Tests should always be performed in the shallowest suitable soil material in order to maximize soil treatment zones.

NUMBER OF TESTS

A minimum of three tests should be conducted within the proposed sewage disposal area. If soil textures, structure and consistence are relatively uniform in the soil horizons or layers selected for testing, the tests can be spaced evenly throughout the area. If soil textures, structure or consistence vary or indicate restrictions to water flow, at least two tests should be conducted in each different layer to help assess variability and select representative rates.

PREPARATION OF THE HOLE

A test pit is excavated to the selected depth of suitable soil. If working with a backhoe, the excavation should stop at least 6 to 12 inches above the test depth. If the test pit meets OSHA and MOSH regulations, then a test can be conducted by entering the pit and preparing a 12-inch square and 12-inch deep hole in the bottom of the test pit. If the test pit depth is greater than 4 feet, it is recommended that the test hole, in the bottom of the pit, be dug with an auger that extends to the land surface. The auger test hole can vary between 3 to 20 inches in diameter; however, the percolation rate must be adjusted to a standard 12-inch square hole.

The sides of the test hole should be scratched with a trowel, knife or sharp pointed instrument to expose natural soil surfaces, and loose material should be removed from the bottom of the test hole if practical.

PRE-SOAK PERIOD

The standard falling head percolation test procedure used in Maryland specifies that a 12-inch square hole be slowly filled with water to a depth of 7 inches above the bottom. When filling the hole, avoid scouring the bottom and stirring up the fines.

After the hole is filled to the 7 inch level, record the time immediately and then allow the water level to drop from the 7 to 6 inch depth for pre-wetting. If the pre-wet percolation rate for the standard hole exceeds the maximum allowable percolation rate the test can be stopped. For auger holes with different diameters, use the attached table to adjust the measured rate to a standard 12 inch hole.

When soil survey data indicate that soils may have a high shrink-swell potential, additional soil saturation and pre-soaking periods should be used to provide better estimates of percolation rates. In any event, it is important that the test hole is sufficiently saturated to simulate conditions of an operating on-site sewage disposal system. In these situations, the test hole should be carefully filled with 12 inches of clear water. This depth of water should be maintained for a minimum of 4 hours and preferably overnight. Automatic siphons, mariotte tubes or float valves may be used to automatically maintain water levels at 12 inches during the pre-soak test period.

MEASUREMENTS OF THE PERCOLATION RATE

The percolation rate for the standard test is determined by measuring the time it takes for the water level to drop from 6 inches to 5 inches above the bottom of the hole. The percolation rate is reported as minutes per inch (MPI).

For soils that are undergoing a longer pre-soak period, the measurement of the percolation rate should be made within 24 hours from the time the pre-soaking period began. Any soil that sloughed into the hole during the soaking period shall be removed and the water level adjusted to six (6) inches above the bottom of the hole. At no time during the test shall the water level be adjusted to greater than six (6) inches above the bottom. Immediately after adjustment, the water level is measured from a fixed reference point to the nearest 1/16 inch at regular intervals. Intervals can be 10, 15, 20 and 30 minutes but should be selected so that the water level does not fall more than 1 inch in any interval. The test shall be continued until two (2) successive water level drops do not vary by more than 10 percent. At least three (3) measurements must be made. After each measurement, the water level shall be adjusted to the six (6) inch level. The last water drop is used to calculate the percolation rate.

The percolation rate is calculated for each test hole by dividing the time interval used between measurements by the magnitude of the last water level drop. This calculation results in a percolation rate in terms of minutes per inch (MPI). To determine the percolation rate for the area, the rates obtained from each hole shall be averaged. If tests in the area vary by more than 20 minutes per inch, variations in soil types are indicated and under these circumstances, percolation rates should not be averaged. For auger holes with different diameters, use the attached table to adjust the measured rate to a standard 12 inch hole.

PERCOLATION RATE CONVERSION TABLE

HOLE DIAMETER (IN.)	CONVERSION UNIT FOR CALCULATING EQUIVALENT MINUTES IN 12 INCH HOLE
3.25	2.79
4.00	2.35
4.50	2.10
6.00	1.66
8.00	1.33
10.00	1.14
12.00	1.00
14.00	0.90
16.00	0.83
18.00	0.77
20.00	0.73

Example: Measured percolation rate of 15 minutes in 4 inch diameter auger hole is equivalent to approximately 35 minutes in standard 12 inch hole.

15 minutes x 2.35 = 35.25

APPENDIX J: CYLINDER INFILTROMETER TEST METHOD

MARYLAND DEPARTMENT OF THE ENVIRONMENT CYLINDER INFILTROMETER PERCOLATION TEST PROCEDURE

DESCRIPTION

A single ring infiltrometer, falling head percolation test measures the time required for a unit depth of clear water to infiltrate into the soil from a standard size infiltrometer. Tests should be conducted only after soil descriptions, limiting zones and water level data indicate that required treatment zones are present and that the soils may be suitable. Representative tests are conducted in the least permeable horizon in the upper 24 inches of the soil and can be used to rank the relative permeabilities of different soil horizons.

The results of the infiltrometer tests are interpreted empirically to confirm soil suitability and select appropriate wastewater hydraulic loading rates for system design. The test, as currently conducted, does not provide an accurate measure of saturated vertical hydraulic conductivity and the results can be highly variable within a site.

MATERIALS AND EQUIPMENT

1) 12 inch diameter cylinder infiltrometer
2) Sledge hammer
3) Posthole digger and round point shovel
4) Pointing trowel
5) Minimum 5 gallons of clear water per test
6) Diffuser or coarse sand
7) Tape measure or folding rule
8) Watch
9) Data forms

LOCATION AND DEPTH OF TESTS

Information from the soil profile descriptions are used to select representative locations and depths for testing. Tests should be performed in the least permeable horizon in the upper 24 inches. If a plow pan exists at depths greater than 12 inches below the surface, representative tests should be conducted in this layer and any least permeable horizons in the upper 24 inches.

NUMBER OF TESTS

A minimum of three tests should be conducted within the proposed sewage disposal area. If soil textures, structure and consistence are relatively uniform within the soil horizons or layers selected for testing, the tests can be spaced evenly throughout the area. If soil textures, structure or consistence vary or indicate restrictions to water flow, at least two tests should be conducted in each layer to help assess variability and select representative rates.

PREPARATION OF THE TEST HOLE

Dig a hole at least 14 to 18 inches in diameter to the depth of the limiting or most restrictive horizon within the upper 24 inches of the soil profile. If working with a backhoe, the backhoe excavation should stop at least 6 to 12 inches above the test depth. If the test pit meets OSHA and MOSH regulations then a test can be conducted by entering the test pit and excavating the remaining soil with a shovel. Carefully drive the cylinder at least 5 inches into the soil. The cylinder should be kept as plumb as possible. Especially avoid rocking the cylinder as it is driven. After having driven the cylinder, press the soil against the inside wall of the cylinder casing. Remove any smeared or compacted surface and expose as much of the natural soil structure as possible. Cover the soil surface with an inch of coarse sand or pea gravel or a diffuser shield. Slowly, fill the cylinder with clear water to at least 6 inches above the soil surface within the infiltrometer. Avoid scouring the bottom and stirring up the fines while adding the water. Remove the diffuser and carefully adjust the water level as necessary to 6 inches.

MEASUREMENTS

Immediately record the depth to the water surface from the top of the cylinder at the seam. A steel tape can slowly be lowered along the seam until it just breaks the surface of the water. This should be repeated to assure an accurate measurement. A hook gage can be used as an alternative to the tape method. Measurements should be read to the nearest 1/16th of an inch. Measurements are taken at regular intervals. Intervals can be 10, 15, 20, 30 and 60 minutes but should be selected so that the water level does not fall more than 1 inch during any interval. If after any interval the water level in the infiltrometer drops to a depth of less than five inches above the soil surface, the level should be adjusted back up to six inches. Highly permeable soils will require a shorter interval. As the test progresses the time interval may be adjusted. The goal is a measurement that is an approximation of vertical permeability under saturated or near saturated conditions. For the purposes of this test a constant rate is considered acceptable. The percolation rate is calculated by dividing the time interval in minutes by the water level drop in inches. This calculation yields a percolation rate in units of minutes per inch (MPI). The test is run until the computed percolation rates for successive intervals vary by less than 10 percent. Measurements must be made over a minimum of three intervals. Before measuring the last interval, the water level in the infiltrometer should be adjusted to six inches. The last interval is used to calculate the percolation rate. Two examples of single ring infiltrometer test results follow.

EXAMPLE					
TEST NO.	**DEPTH FROM TOP OF CYLINDER (in.)**	**ELAPSED TIME (min.)**	**MEASURED DROP (in.)**	**RATE (min./in.)**	**% DIFFERENCE IN RATE**
1	12 8/16 13 13 6/16 12 8/16 12 14/16	N/A 10 10 N/A 10	N/A 0.500 0.375 N/A 0.375	N/A 20 27 N/A 27	N/A N/A 35% N/A-Repour 0%
Percolation Rate = 27 minutes per inch (MPI)					
2	12 3/16 12 13/16 13 5/16 12 3/16 12 9/16 12 14/16 13 2/16 12 3/16 12 9/16	N/A 20 20 N/A 20 20 20 N/A 30	N/A 0.625 0.500 N/A 0.375 0.312 0.250 N/A 0.375	N/A 32 40 N/A 53 64 80 N/A 80	N/A N/A 25% N/A -Repour 32% 21% 25% N/A-Repour 0%
Percolation Rate = 80 minutes per inch (MPI)					

Revised and Corrected 10/20/09

APPENDIX K: HYDRAULIC CONDUCTIVITY TEST METHODS

PERMEABILITY TESTS BELOW A WATER TABLE

The piezometer and slug test methods (as described by Bouwer and Jackson, 1974) are presented here for determining the *K* value (hydraulic conductivity) below a water table. There are other methods such as the auger hole, tube and piezometer methods (Bouwer and Jackson, 1974) but the slug test well method has been chosen by the Department as the best determination for permeability of saturated soils in predicting the ability of these soils to accept treated sewage effluent and to be able to compare conditions from site to site. Among the available small-scale tests, falling head tests and rising head (pump out) tests have been used for several decades (Pandit and Miner, 1986). These methods are for use in determining a "permeability rate" where either the Bermed Infiltration Pond (BIP) or the Sand-Lined Trench (SLT) sewage disposal methods are proposed.

SLUG TEST USING A WELL

The most recent experience (1992–1993) has determined the simplest and most reliable method of obtaining accurate hydraulic conductivity measurements in saturated unconfined or confined or stratified aquifers is the "slug test method" using a well screened in a portion or throughout the entire aquifer thickness (Bouwer and Rice, 1976; Bouwer, 1989). When using the "slug test method," defined as when determining the hydraulic conductivity "from the rate of the rise of the water level in a well after a certain volume or "slug" of water is suddenly removed from the well" (Bouwer and Rice, 1976), care must be taken to prevent drawing the water down below the aquifer or gravel pack around the screen. The geometry of most groundwater wells is outside the range in geometry covered by the equations or tables for the auger hole in piezometer methods (Bouwer and Rice, 1976). Procedures and equations for the "slug test method" are presented based on Bouwer and Rice theory (Bouwer and Rice, 1976; Bower, 1989).

1. Select a site (near a water table monitoring hole is optional).

2. Calculate the depth from ground surface to the porous zone to be tested from soil profile. Depth to porous soil (DPS) = ___ inches.

3. Bore hole to total depth of test, noting exact location from ground surface of porous zone or zone to be tested.

4. Place casing and screen in hole (use clean screen with proper slot size) .010 works well in most cases.

5. Place clean sand or well driller's gravel pack (the hydraulic conductivity of the gravel/sand envelope must be much higher than the aquifer material) next to screen and to upper limit o. cavity to be tested.

6. Place bentonite (pellets) grout on sand/gravel pack to depth which seals out all soil not to be tested and to a point which intersects with impermeable soils above.

7. Develop the well until fine materials are reasonably well removed (use muddy water as an indicator). Allow water table to stabilize (usually 24 hours) and run test either falling head or pump out method.

SLUG TEST EQUATIONS AND CALCULATIONS

The basic formula for hydraulic conductivity K for the slug test method (see FIGURE K.1) is:

(1)
$$K = \frac{r_c^2 \ ln \ (R_e/r_w)}{2L_e} \ \frac{1}{t} \ ln \ \frac{y_o}{y_t}$$

Where: K = hydraulic conductivity of aquifer around well;

L_e = length of screened, perforated or otherwise open section of well;

y = vertical difference between water level inside well and static water table outside well;

R_e = effective radial distance over which y is dissipated;

r_w = radial distance of undisturbed portion of aquifer from centerline;

r_c = the inside radius of the casing if the water level is above the perforated or otherwise open portion of the well;

t = the time interval for the water level to rise or fall from y_o to y_t, $y_o = y$ at time zero; and $y_t = y$ at time t.

Because y and t are the only variables in equation (1), a plot of $ln\ y_t$ versus t must show a straight line. Thus, a number of y and t measurements can be taken and the $ln\ y_t$ versus the t for each plotted on semilogarithmic paper (FIGURE K.2). The straight line through the data points can be used to select two values of y, namely y_0 and y_t, along with time interval t between them for substitution into equation (1) (Bouwer, 1989). For values of $ln(R_e/r_w)$, based on analog analyses to evaluate R_e for various system geometries, the data can be fitted into two equations, one for the case where $L_w < H$ and one where $L_w = H$. The resulting equations are:

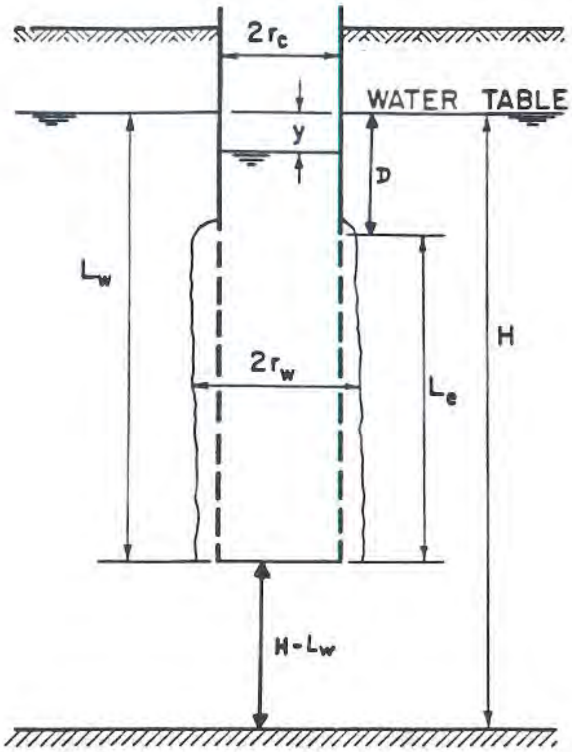

FIGURE K.1

IMPERMEABLE

Geometry and symbols for slug test on partially penetrating, partially screened well in unconfined aquifer with gravel pack and/or developed zone around screen.

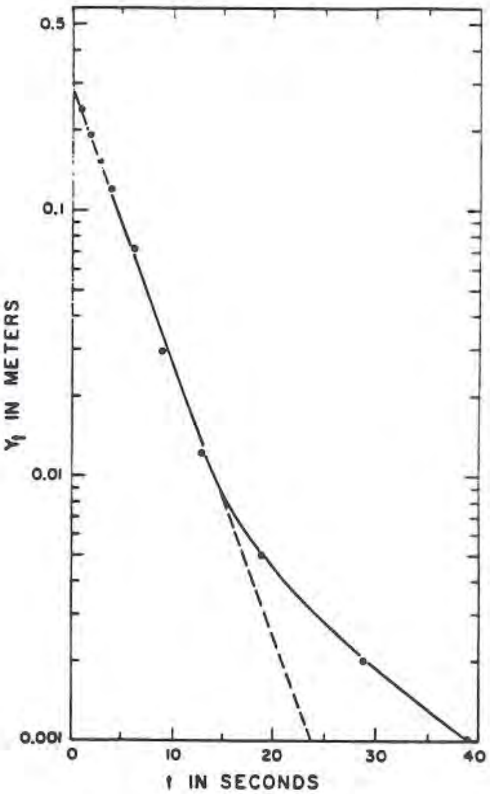

FIGURE K.2

Graph of *log* y_t versus *t* for slug test on well in Salt River Bed, 27th Avenue, Phoenix, Arizona.

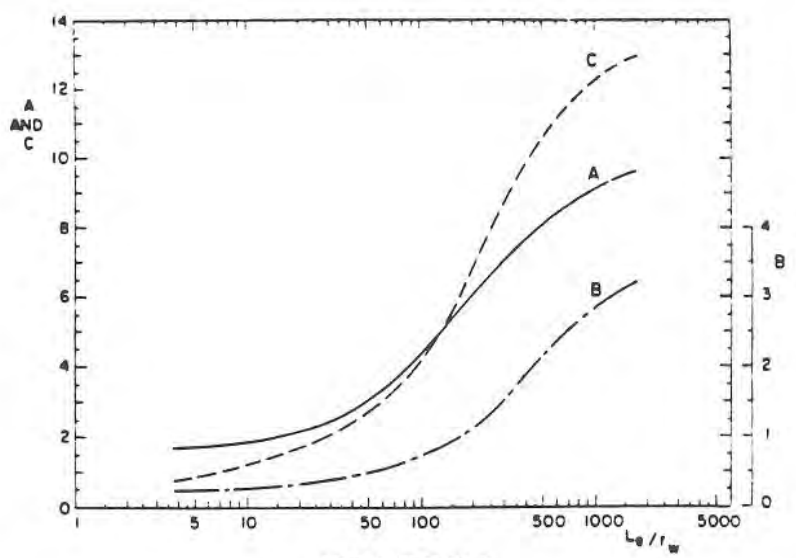

FIGURE K.3

Dimensionless parameters A, B, and C as a function of L_e/r_w for calculation of $1n(R_e/r_w)$.

For $L_w < H$ use Equation (2).

(2) $$\ln(R_e/r_w) = [1.1/\ln(L_w/r_w) + (A + B\ \ln((H-L_w)/r_w) / (L_e/r_w)]^{-1}$$

For $L_w = H$ use Equation (3).

(3) $$\ln(R_e/r_w) = [1.1/\ln(L_w/r_w) + (C/(L_e/r_w)]^{-1}$$

Where *A*, *B*, and *C* are dimensionless numbers plotted in FIGURE K.3 as a function of L_e/r_w.

NOTE: A qBasic computer program has been developed to run the calculations for this method. The program is entitled KSLUG.BAS and instructs user to insert specific parameters with specified units and then calculates the *K* value in inches/hour.

PIEZOMETER METHOD

In some cases the piezometer method has been used successfully. In the piezometer method a hole is bored into the soil to a depth below the water table and cased except for the cavity at the bottom of the casing (Bouwer and Jackson, 1974). The water seeps into the cavity and rises to an equilibrium level, which is the water table. The equilibrium level is recorded. A 4-inch diameter hole is preferred with a minimum cavity into the porous saturated material of 12 inches. The cavity must remain open. In sandy soils either a screened liner or clean stone may be placed in the cavity. Grouting may be necessary when using a casing smaller than upper hole diameter. It is possible tc run the test with the unlined cavity; however, this has not been practical where the porous silt is a caving material. After the water table has reached equilibrium (when performing a test adjacent to a water table observation hole the piezometer may be filled with water to the proper level immediately at the time of construction using the observation hole to determine the water table level). Clear water is then added (or removed by bailing or pumping for pump out method) to the casing above the water table. Multiple time and water level readings are obtained until the water level nears the original water table. The *K* in inches/hour is then calculated using equation (4) and FIGURES K.4 or K.5 and equations (5), (6) or (7) depending on values of *L/a* and *L/S+L* (NAVFAC DM-7.1, 1982).

If the *K* value from the falling head test is too low or stabilizing the cavity becomes difficult the **slug test well method should be utilized.** The reason for using the falling head test and not the variable pumpout method is the piezometer with open cavity does not respond well to being pumped.

(4) $$K\ in./hr. = \frac{\pi r^2 \ln(y_o/y_1)}{C\ t} \times 60$$

C obtained from TABLE K.1 or FIGURE K.6.

Where: K = hydraulic conductivity of aquifer around well;

L = length of cavity or otherwise open section of piezometer (inches);

y = vertical difference between water level inside casing and static water table (inches);

C = a factor depending on the geometry of the system (has the dimension of a length). (See TABLE K.1 or FIGURE K.6 to obtain C from C/a);

a = radius of the cavity (inches);

r = the inside radius of the casing (inches);

t = the elapsed time interval for the water level to rise or fall from y_o to y_t. $y_o = y$ at time zero; and $y_t = y$ at time t (minutes);

D = distance from static water table to top of cavity or bottom of casing (inches); and

S = distance from cavity bottom to lower confining unit (inches).

For conditions: $L/a>8$, calculate K using equations (5), (6) or (7).

Where $L/S+L>0.2$ and <0.85 use Equation (5);

(5)
$$K \text{ in./hr.} = \frac{r^2 ln(L/a)}{2Lt} ln(y_o/y_1) \times 60$$

And where $L/S+L \leq 0.2$ use Equation (6);

(6)
$$K \text{ in./hr.} = \frac{\Pi r}{C_1 t} ln(y_o/y_1) \times 60$$

(C_1 obtained from FIGURE K.7.)

And where $L/S+L=1.0$ use Equation (7);

(7)
$$K \text{ in./hr.} = \frac{5.3r^2}{2Lt} ln(y_o/y_1) \times 60$$

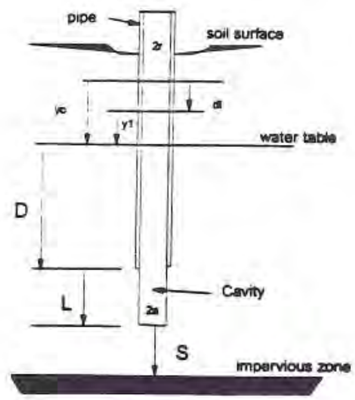

FIGURE K.4
FALLING HEAD

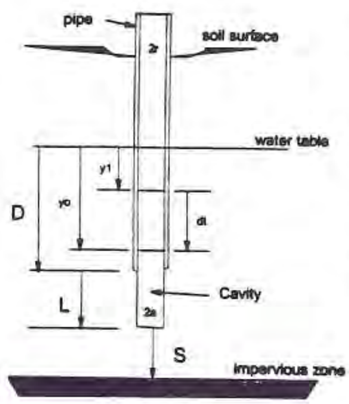

FIGURE K.5
PUMP-OUT METHOD

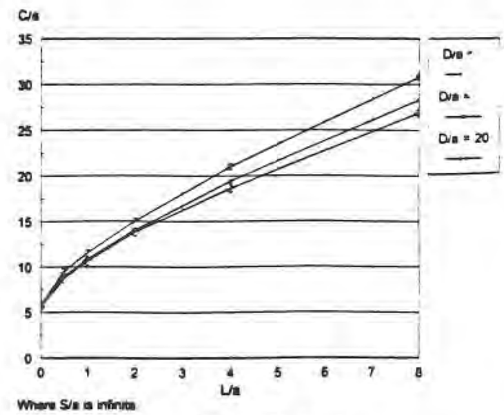

FIGURE K.6

Shape factor for the pipe-cavity method of determining the soil hydraulic conductivity. After Smiles and Youngs.

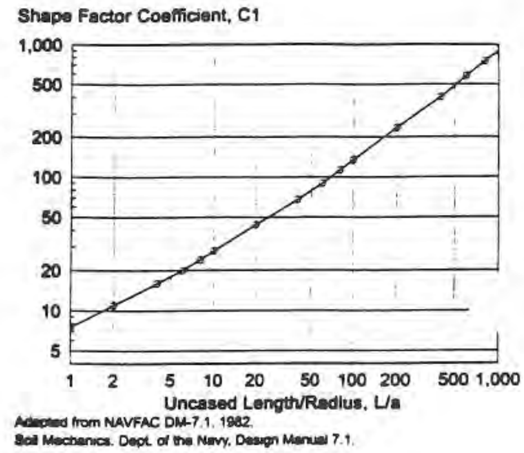

FIGURE K.7

TABLE K.1

Values of *C/a* for piezometer method with cylindrical cavities (Youngs, 1968).

L/a	*D/a*	*S/a* FOR IMPERMEABLE LAYER							*S/a* FOR INFINITELY PERMEABLE LAYER						
		∞	8.0	4.0	2.0	1.0	0.5	0	∞	8.0	4.0	2.0	1.0	0.5	0
0	20	5.6	5.5	5.3	5.0	4.4	3.6	0	5.6	5.6	5.8	6.3	7.4	10.2	∞
	16	5.6	5.5	5.3	5.0	4.4	3.6	0	5.6	5.6	5.8	6.4	7.5	10.3	∞
	12	5.6	5.5	5.4	5.1	4.5	3.7	0	5.6	5.7	5.9	6.5	7.6	10.4	∞
	8	5.7	5.6	5.5	5.2	4.6	3.8	0	5.7	5.7	5.9	6.6	7.7	10.5	∞
	4	5.8	5.7	5.6	5.4	4.8	3.9	0	5.8	5.8	6.0	6.7	7.9	10.7	∞
0.5	20	8.7	8.6	8.3	7.7	7.0	6.2	4.8	8.7	8.9	9.4	10.3	12.2	15.2	∞
	16	8.8	8.7	8.4	7.8	7.0	6.2	4.8	8.8	9.0	9.4	10.3	12.2	15.2	∞
	12	8.9	8.8	8.5	8.0	7.1	6.3	4.8	8.9	9.1	9.5	10.4	12.2	15.3	∞
	8	9.0	9.0	8.7	8.2	7.2	6.4	4.9	9.0	9.3	9.6	10.5	12.3	15.3	∞
	4	9.5	9.4	9.0	8.6	7.5	6.5	5.0	9.5	9.6	9.8	10.6	12.4	15.4	∞
1.0	20	10.6	10.4	10.0	9.3	8.4	7.6	6.3	10.6	11.0	11.6	12.8	14.9	19.0	∞
	16	10.7	10.5	10.1	9.4	8.5	7.7	6.4	10.7	11.0	11.6	12.8	14.9	19.0	∞
	12	10.8	10.6	10.2	9.5	8.6	7.8	6.5	10.8	11.1	11.7	12.8	14.9	19.0	∞
	8	11.0	10.9	10.5	9.8	8.9	8.0	6.7	11.0	11.2	11.8	12.9	14.9	19.0	∞
	4	11.5	11.4	11.2	10.5	9.7	8.8	7.3	11.5	11.6	12.1	13.1	15.0	19.0	∞
2.0	20	13.8	13.5	12.8	11.9	10.9	10.1	9.1	13.8	14.1	15.0	16.5	19.0	23.0	∞
	16	13.9	13.6	13.0	12.1	11.0	10.2	9.2	13.9	14.3	15.1	16.6	19.1	23.1	∞
	12	14.0	13.7	13.2	12.3	11.2	10.4	9.4	14.0	14.4	15.2	16.7	19.2	23.2	∞
	8	14.3	14.1	13.6	12.7	11.5	10.7	9.6	14.3	14.8	15.5	17.0	19.4	23.3	∞
	4	15.0	14.9	14.5	13.7	12.6	11.7	10.5	15.0	15.4	16.0	17.6	20.1	23.8	∞
4.0	20	18.6	18.0	17.3	16.3	15.3	14.6	13.6	18.6	19.8	20.8	22.7	25.5	29.9	∞
	16	19.0	18.4	17.6	16.6	15.6	14.8	13.8	19.0	20.0	20.9	22.8	25.6	29.9	∞
	12	19.4	18.8	18.0	17.1	16.0	15.1	14.1	19.4	20.3	21.2	23.0	25.8	30.0	∞
	8	19.8	19.4	18.7	17.6	16.4	15.5	14.5	19.8	20.6	21.4	23.3	26.0	30.2	∞
	4	21.0	20.5	20.0	19.1	17.8	17.0	15.8	21.0	21.5	22.2	24.1	26.8	31.5	∞
8.0	20	26.9	26.0	25.5	24.0	23.0	22.2	21.4	26.9	29.6	30.6	32.9	36.1	40.6	∞
	16	27.4	26.3	25.8	24.4	23.4	22.7	21.9	27.4	29.8	30.8	33.1	36.2	40.7	∞
	12	28.3	27.2	26.4	25.0	24.1	23.4	22.6	28.3	30.0	31.0	33.3	36.4	40.8	∞
	8	29.1	28.2	27.4	26.1	25.1	24.4	23.4	29.1	30.3	31.2	33.8	36.9	41.0	∞
	4	30.8	30.2	29.6	28.0	26.9	25.7	24.5	30.8	31.5	32.8	35.0	38.4	43.0	∞

PREPARATION OF PIEZOMETER HOLE AND CAVITY FOR PERMEABILITY TEST WHEN DRIVING UPPER CASING

1. Select a site (near a water table monitoring hole is optional).

2. Calculate the depth from ground surface to the porous zone to be tested from soil profile. Depth to porous soil (DPS) = ___ inches.

3. Subtract 4 to 6 inches from DPS depth, this will become the hole depth prior to driving casing to obtain a seal. Be sure casing is at least 6 to 12 inches longer than depth DPS so there will be some stickup above ground surface.

4. Bore a hole using a 4.5+ inch auger to a depth of 3 in.

5. Insert a piece of solid thin wall PVC sewer and drain pipe, or other suitable metal or plastic pipe, into hole to bottom.

6. Drive the casing into the soil 4 to 6 inches to seal around the bottom of the casing, thus preventing water from rising up the annular space.

7. Bore a cavity, using an auger less than 4 inches in diameter, approximately 12 inches in depth below the casing bottom (being certain the cavity is in the aquifer material). Measure and record the exact diameter of a hole cut by the auger used.

8. Pour clean water into the hole to a depth equal to the equilibrium water table.

9. While the hole is stabilizing, calculate depth and prepare equipment and water for performing the test. Add water to the stickup portion of the casing and obtain multiple readings of time and water level as the water falls. Calculate the K value in the field to decide if further testing is warranted. Check the cavity depth due to siltation or caving at the end of the test and before calculating the K value. If the cavity has caved in to the bottom of the casing, and the K value is >1.0 in./hr. using the original cavity configuration obtained from the borehole dimensions, no further testing is considered necessary. If the K value is too low the cavity should probably be rebored and clean stone added to the cavity portion only and the test repeated. If the K value is still too low or the cavity cannot be kept reasonably free of fines the piezometer probably should be abandoned in favor of the slug test well method.

Note: A qBasic computer program has been developed to run the calculations for this method. The program is entitled KOK.BAS and instructs user to insert specific parameters with specified units and then calculates the *K* value in inches/hour.

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HYDRAULIC CONDUCTIVITY TEST DATA SHEET
PIEZOMETER METHOD

File No. _____

Testhole No. _____ **Conducted By:** ________________ **Date:** _______

Testhole Dimensions (inches)

X = _____

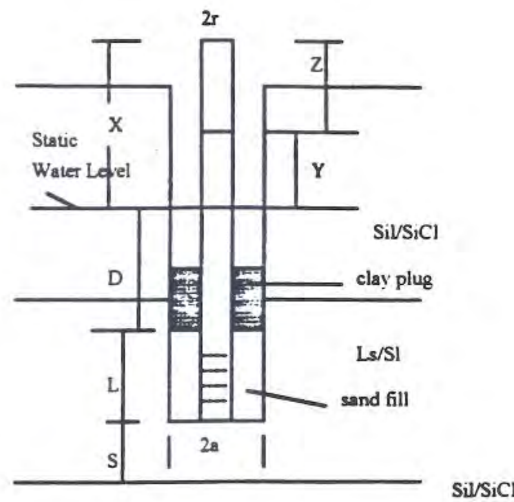
a = _____

r = _____

D = _____

L = _____

S = _____



TEST DATA
Falling Head

Clock Time	Elapsed Time (t)	Measure. (Z)	Head (X-Z=Y)

TEST DATA
Recovery

Clock Time	Elapsed Time (t)	Measure. (Z)	Head (X-Z=Y)