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INTRODUCTION

Approximately one-third of all housing units in the United States are not connected to central sewer collection systems. These units rely upon on-site wastewater systems to treat and dispose of domestic sanitary sewage. In Massachusetts there are more than 500,000 housing units that use on-site systems to dispose of domestic wastewater. It is estimated that over 70 million gallons of renovated water are returned daily to the ground waters of the Commonwealth via on-site sewage disposal (OSD). This source of recharge to Massachusetts' aquifers is threatened, however, by incomplete treatment of the discharged wastewater. Disposal of inadequately treated wastewater from OSD systems can significantly contribute to groundwater pollution, endangering the groundwater resource that serves as a primary source for drinking water for many Massachusetts communities.

Disposing of inadequately treated domestic wastewater raises serious environmental and public health concerns that can be addressed by properly siting, designing, constructing and operating on-site sewage disposal systems. Over the years states have updated their regulations governing OSD systems to reflect their increasing knowledge of these systems. In Massachusetts, the state regulations governing OSD systems are contained in 310 CMR 15.000: The State Environmental Code (Title 5). This regulation sets forth a number of requirements intended to improve the siting, design and installation of OSD systems and to ensure safe and non-polluted surface water and groundwater.

Title 5 was significantly revised in 1995 to include an improved site assessment procedure that would be conducted by a Massachusetts-approved soil evaluator. This individual would evaluate the potential of a proposed site for on-site sewage disposal by determining the textural class (relative proportion of sand, silt and clay) of each soil layer present at the site and estimating the maximum groundwater elevation beneath the discharge location. In addition, the soil evaluator would note any potential restrictions that would affect the suitability of the site. These restrictions could include such things as the presence of flow-restricting layers, the absence of 4 feet of naturally-occurring pervious soil, or any other aspects of the site that could negatively affect system performance. The change in Massachusetts to a soil-based site evaluation system followed a national trend that was initiated over 20 years ago. Most New England states have since adopted such soil-based OSD regulations.

WASTEWATER

The quantity and quality of sewage varies from house to house. Some dwellings are occupied by a few retired people, while others contain large extended families. In addition to the actual number of residents, the quality of the wastewater is much affected by the practices of family members. Some individuals use large quantities of water, but may dispose of only limited quantities of solids, resulting in fairly diluted wastewater. On the other hand, some persons and families produce large amounts of solids that have the potential to quickly overwhelm the OSD system. For example, houses equipped with garbage grinders tend to produce large amounts of solids that may cause system failure, particularly when the use of such an appliance was not anticipated in the design of the original system.

The daily volume of wastewater generated by an "average" person ranges from 45 to 60 gallons of wastewater per day, with an average of about 50 gallons per day. While the combined volume of toilets and garbage disposals may only constitute 30% of the daily flow, the strength of these components in terms of solid material (suspended solids) far exceeds that value. Laundry and bathing contribute a large portion of the total daily wastewater volume; however, these components only contribute a small portion of the solids and nutrients. Use of low-volume toilets, low-flow showerheads, and high-efficiency washers and dishwashers reduce the overall volume of the flow. The net effect is a more concentrated wastewater that requires greater treatment efficiency. Title 5 directs the designer of the OSD system to assess potential characteristics of the proposed wastewater and incorporate these into the design.

When discussing OSD systems, a distinction is made between actual and design flow. As stated previously, actual flow varies from person to person and therefore cannot be used to design an OSD system. The design must anticipate the potential number of occupants in a dwelling, rather than the number of individuals that actually will live there. Title 5 therefore employs a design flow that is much larger than the actual flow. Such an approach addresses peak loading periods of OSD systems (morning showers, breakfast and evening meals, cleanup) and is a standard engineering design practice used to prevent premature failure of the OSD system.

CONVENTIONAL OSD SYSTEMS

A conventional OSD system consists of the following three components: a septic tank, a distribution box, and a disposal area known as the soil absorption system (SAS). These components are illustrated in Figure 1-1.

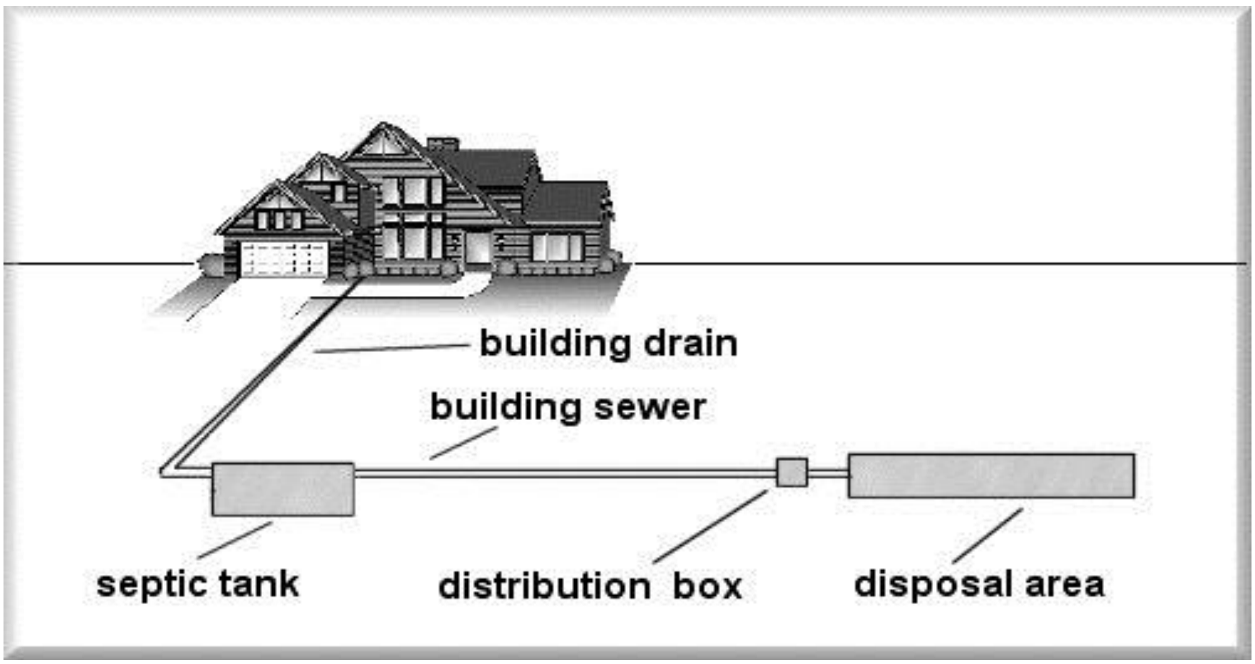


Figure 1-1. Major components of a conventional OSD system

<u>Septic Tank</u>

The septic tank is first in the series of components that make up the OSD system. It is a large watertight vessel generally made of concrete or other durable material. The septic tank is a pretreatment unit whose purpose is to receive raw household wastewater from the plumbing system, separate solids from the liquid portion, and discharge the clarified liquid to a soil absorption system for further treatment and disposal. When raw sewage enters the septic tank from the building sewer, the flow is directed downward through an inlet tee. As energy in the wastewater stream is dissipated, particles heavier than water slowly sink to the bottom of the tank and accumulate as sludge. The lighter particles, including grease, oils and waxes, float to the top and accumulate as a layer of scum. The floating scum is prevented from exiting the septic tank with the reasonably clear effluent by an outlet tee that extends below the bottom of the scum layer.

Removal of solids from the wastewater is the principal function of the septic tank; some anaerobic treatment takes place within the tank. The tank is sized to provide a wastewater residency time of 2 to 3 days even when partially filled with sludge. This period should provide for settlement of all but the smallest particles, which generally remain in suspension for a long period of time.

Table 1-1 shows the degree of pollutant removal typically obtained in the septic tank. Suspended solids (SS) are reduced to less than 40% of the original volume. The amount of oxygen required to oxidize all organic matter, expressed as biochemical oxygen demand (BOD), is reduced to a value slightly above 40%. Reductions in nitrogen and phosphorus concentrations are not as pronounced as the SS and BOD values because these nutrients are dissolved rather than solid.

	Total SS (mg/L)	BOD (mg/L)	Nitrogen (mg/L)	Phosphorus (mg/L)
Household Sewage	400	350	80	35
Septic Tank Effluent	140	150	50	20

Table 1-1. Concentrations of selected parameters in household sewage and septic tank effluent

Table 1.1 clearly illustrates that the effluent exiting the septic tank still contains significant levels of pollutants and will require further treatment prior to reaching groundwater.

<u>Distribution Box</u>

The distribution box (d-box) is located between the septic tank outlet and the disposal area/SAS (Figure 1-1). As with septic tanks, the d-box is generally constructed of concrete but may be constructed of plastic or other materials approved by MassDEP. The purpose of the d-box is to receive the flow of clarified effluent exiting the septic tank and distribute it evenly through a series of outlets to the SAS.

<u>Disposal Area/Soil Absorption System</u>

Final treatment of effluent in the on-site sewage disposal system occurs in the SAS and the soils beneath it. As the partially treated effluent enters the disposal area, it begins to percolate through the stones placed in the soil absorption system (SAS) and then into the underlying soil. Very shortly after the SAS is placed in use, a biological "mat" begins to form at the interface between the stones and the soil. This biological mat, or "clogging layer", is made up of millions of bacteria whose role is to break down the remaining organic matter in the effluent. The mat enlarges in time as the system receives more use. Additionally, the mat slows the infiltration of the liquid into the soil, thus maintaining unsaturated soil conditions below the mat. As effluent passes through the mat and then through the unsaturated soil below, pathogenic organisms and other pollutants are removed, thus allowing the liquid to recharge groundwater without posing a public health risk.

There are several types of SASs that are acceptable for use under Title 5. The choice of which particular system to use depends upon local site conditions, area available for on-site sewage disposal, and designer's preference. Each type of SAS must provide a temporary retention area for the liquid sewage and a stone interface with the surrounding soil to allow for development of the biological slime layer that builds up in a functioning sewage system. Additionally, the SAS must be located in pervious soil that is capable of accepting and dispersing the liquid sewage being discharged into the facility from a septic tank. In order to assure this, Title 5 requires that a soil evaluation be conducted for each OSD system and that it be conducted by soil evaluators certified by MassDEP.

As sewage is generated and sent to the septic tank, an equal amount of effluent will leave the septic tank and enter the SAS. In most gravity-fed systems, only the first 5 to 10 feet of distribution pipe within the SAS will contribute to the distribution of effluent. In new OSD systems, the fact that effluent flows only to a small portion of the SAS leads to concentrated, saturated and rapid downward flow. Rapid flow does not allow for proper treatment and most septic systems will therefore provide very little treatment during the initial months following installation. After a short time, the suspended solids in the septic tank effluent increasingly become entangled in the labyrinth of soil pores at the gravel/soil interface. Once this process starts it accelerates as more and more particles become trapped. After several months, most of the pores have become clogged in a process called progressive clogging. The organics in the clogging layer (biomat) become a food substrate for the plethora of microorganisms present in septic tank effluent. These organisms strongly enhance anaerobic digestion of the accumulated organic materials and in turn produce slimes and inorganic compounds such as iron sulfide (FeS). These compounds make the developing clogging layer even less pervious and after about a half year the clogging layer is complete and in equilibrium with the septic tank effluent.

Development of the biomat or clogging layer was originally thought to interfere with the disposal of sewage. Later research indicated that the presence of the clogging layer strongly enhanced treatment efficiency. In fact, the presence of unsaturated soil below the leaching facility is essential for effective effluent treatment. Unsaturated conditions prevent the rapid movement of effluent through large pores and force the effluent to flow through the medium and small pores of the soil matrix. Flow rate is substantially reduced under aerobic conditions, thereby increasing the residence time within the soil environment. For example, flow rate is lowered from a few minutes per inch in a saturated sand to 20 to 30 days under unsaturated conditions. Unsaturated flow promotes entrapment of pollutants and pathogens, while oxidizing conditions enhance the die-off and oxidation of pathogens and organics.

As Table 1.1 indicates, effluent exiting the septic tank still contains significant quantities of suspended organic solids that need to be converted to more environmentally benign compounds. In addition, the effluent contains nutrients, including nitrogen and phosphorus, and literally billions of microorganisms, a portion of which may be pathogenic. In recent years, regulatory agencies have become more diligent in pursuing the potential environmental and public health risks that septic systems may pose. Proper siting, design and installation ensure the development of a clogging layer and/or the presence of unsaturated and oxidizing conditions below the leaching facility. It is the task of the soil evaluator to ensure that the OSD system is properly sited in a location that guarantees almost perpetual operation of the system in a manner that enhances environmental quality and eradicates pathogens.

EFFICACY OF ON-SITE SEWAGE DISPOSAL SYSTEMS

Suspended Solids and BOD

As explained previously, any system that has just been placed in operation has an under-developed clogging layer whereby the largest soil pores still remain open and permit some transport of suspended solids to the natural soil underlying the leaching facility. Once the clogging layer in the leaching facility has matured, the bulk of the suspended solids are retained in the clogging layer. These organic compounds are degraded by microbial action into carbon dioxide and water. In unsaturated soil, large pores that potentially can transport contaminants rather rapidly are empty and filled with air. The septic tank effluent is forced to travel a tortuous path through the soil matrix, mainly through relatively small pores and films of water covering the soil particles. The wastewater percolates through the unsaturated soils less rapidly than it would in saturated soils, and travel times increase significantly. This results in greater residence times of wastewater in the soil environment, from a few hours to weeks, enhancing treatment efficiency. Some dissolved organics may travel with the septic tank effluent through the clogging layer into the soil below the leaching facility and are oxidized in the unsaturated soil below the leaching facility. By the time the wastewater reaches the groundwater, essentially all organics have been removed by oxidation. Parallel to the reduction in organics from the percolating wastewater, BOD and chemical oxygen demand (COD) will diminish to background levels.

Nutrients

Domestic wastewater contains a host of nutrients that can be considered contaminants, including sodium, potassium, nitrogen and phosphorus. The latter two elements are of most concern from an environmental point of view. Each of the elements may be limiting biological processes. Additions of the nutrient that is in shortest supply will result in strong growth of plants, algae, and microorganisms until the element is used up or another nutrient becomes limiting. Phosphorus (P) tends to be limiting in most freshwater systems, whereas nitrogen (N) tends to be limiting in coastal regions. Release of nitrogen to the coastal environment will result in increased plant and algae growth. Upon die-off of the excess plant material, oxygen is used up rapidly and the entire aquatic system may turn anaerobic. This results in fish kill and excess accumulation of the plant and animal remains. Phosphorus generally regulates aquatic plant production in freshwater environments, although occasionally nitrogen may be limiting during the late summer months, even in freshwater systems.

Phosphorus in septic effluent tends to be in the dissolved orthophosphate form, which moves readily through the clogging layer. In the unsaturated zone below the leaching facility, the phosphorus is removed from the wastewater by chemical precipitation. In acid soils the phosphate will form insoluble compounds with aluminum and iron; in calcareous soils it precipitates with calcium or magnesium. Most Massachusetts soils are fairly acidic, with a pH value of around 5, and iron is the principal co- precipitant with the orthophosphate. Some soils in Berkshire and northern Worcester counties are more acidic, with a pH around 3.8, and there both iron and aluminum precipitate phosphorus. West of the Housatonic River soils tend to be calcareous, and the phosphate will precipitate with calcium. Research indicates that 4 feet of unsaturated soil (5 feet in sandy soils) provides sufficient amounts of iron and aluminum to sustain phosphorus removal for a prolonged time period. Experience with existing systems tends to reinforce the idea that phosphorus does not seem to be a problem in properly engineered systems. Problems have been reported in areas where systems (often cesspools) have been installed in seasonally wet soils.

Nitrogen occurs in the septic tank in the soluble ammonium (NH_4^+) form. Once the effluent leaches through the clogging layer into the unsaturated and aerated subsoil, the ammonium is quickly converted into nitrate (NO_3^-). This latter compound, being negatively charged, is repelled by the negatively charged soil particles and is not retained in the soil. Every conventional system, even when operating under optimal design conditions, will leach nitrogen. For a family of four living on a one-acre lot, taking into account the diluting effect of precipitation-derived groundwater recharge, the final concentration of nitrate attributed to the effluent is about 6 mg/L. This is well below the federal drinking water standard of 10 mg/L.

Pathogens

Sewage by its very nature contains many microorganisms. The majority of these are benign and will not cause any problems for humans. However, pathogenic microorganisms, including bacteria and viruses, do occasionally occur, depending on the health status of the dwelling's inhabitants. Research has indicated that as far as microorganisms are concerned, the degree of purification in a leaching facility depends strongly on the loading rate, that is, the amount of effluent applied per square foot.

Current Title 5 loading rates are approximately one-third of what was permitted under the old code. The end result is that under the current code less effluent per unit area of soil is applied, resulting in lower loading rates and presumably better purification of the wastewater. This effect is most prevalent in coarse soils. Whereas lower wastewater loading rates enhance removal and die-off of bacteria, the same may not be true for the much smaller viruses. High loading rates and saturated soil conditions in the zone beneath the leaching facility should be avoided because of potential problems with pathogens.

There have been published reports expressing concern about the release of pathogenic viruses by septic systems. These same concerns may, under certain conditions, also apply to standard municipal wastewater treatment plants. The advance of alternative technologies may bring about better treatment potential of these microorganisms. Until that time, the low-cost gravity septic system discharging through the soil into the groundwater will remain the preferred choice of many designers. Prediction of the fate of viruses in the unsaturated soil environment is difficult because of the difference in surface properties as well as the electric charge between the various microbial groups. Some municipalities have increased setback requirements because of pathogen concerns. This practice, however, may not be entirely correct because some pathogens will move under saturated flow conditions, while the majority of microorganisms are trapped and destroyed within the unsaturated soil zone underlying the leaching facility.

THE SOIL EVALUATOR

As we've seen, actual treatment of effluent, in the form of biological and/or non-biological processes that result in the complete or partial removal of wastewater constituents, generally takes place in the soil environment beneath the SAS. The Commonwealth of Massachusetts, having recognized that soil is a vital component of the OSD system, has implemented a methodology for characterizing and assessing a site's ability to accept and treat sanitary wastewater effluent. This methodology is known as soil evaluation and 310 CMR 15.000, Title 5, requires that it be performed by a "Soil Evaluator" certified by the Commonwealth of Massachusetts.

You are attending this course to learn the fundamental skill set required to become a soil evaluator and to develop and demonstrate sufficient proficiency in these skills to be certified as a Massachusetts-approved soil evaluator. Over the next couple of months, through classroom presentations and hands-on field training sessions, you will be exposed to a significant amount of information pertaining to soils, the water table, glacial geomorphology, and Title 5. You will learn to characterize and describe soils based upon soil texture and color. You will learn about soil-forming processes and the development of soil horizons. You will learn about the chemical processes that lead to the development of color in soils and how to use that information to determine the seasonal high water table.

Most soils found in Massachusetts are relatively young and were formed in parent materials deposited during or just after the last period of New England glaciation. As such, you will learn about glacially-derived sediments, glacial depositional processes and glacially-deposited landforms. This information will prove invaluable when preparing to conduct a soil evaluation and when selecting specific sites to evaluate.

Additionally, you will learn about the sections of Title 5 that relate to soil evaluation and site assessment. You will learn how to evaluate a site's ability to accept wastewater by means of percolation testing. You will learn the minimum requirements a site must meet to be approved for on-site sewage disposal, as well as what site limitations will prevent a site from being approved. Lastly, you will learn how to complete the documentation required by Title 5 to be submitted to the appropriate approving authority.

GEOLOGIC DEPOSITS

Parent material governs what types of minerals are in the soil and the color of the soil, and influences many soil properties such as permeability, infiltration, and pH. While some soils develop by weathering of the underlying bedrock (residual soil), New England soils have been formed from material that has been transported through glacial processes or events that occurred post glaciation. There are six broad groupings of geologic sediments (soil parent material) that occur within Massachusetts –

1.) glacial till

2.) glacial outwash

3.) lacustrine (lakebed) deposits

4.) marine silts and clays

5.) coastal dune deposits

6.) floodplain (alluvial)

Some parent materials were deposited either during the glaciation or shortly thereafter as the glacier was melting (till, glacial outwash, lacustrine deposits and marine silts and clays), while other parent material is reflective of more recent geologic processes (organic deposits, coastal dune deposits (eolian) and floodplain (alluvium) deposits).

A basic geologic understanding of a site is crucial to understanding how a site will impact adjacent areas and will help to narrow the focus of an on-site investigation to key issues.

GLACIAL TILL

Figure 2-1(a)

Figure2-1(b)

Figure 2-1. Examples of till outcrop (a) and in a trench (b). Till was deposited within or beneath glacial ice showing the unsorted, heterogeneous nature with a wide particle size distribution from clay size particles to boulders

<u>Till</u> – Glacial till is predominantly unsorted and nonstratified debris consisting of a heterogeneous mixture of clay, silt, sand, gravel, stones and boulders that has been deposited directly by a glacier. This material is mostly derived from the subglacial erosion and entrainment by the moving ice of available unconsolidated sediments. Bedrock can also be eroded through the action of glacial plucking and abrasion and the resulting clasts of various sizes will be incorporated into the moving ice.

Glacial till can be subdivided into two broad groupings:

1. Compact till or lodgement till also referred to as dense basal till
2. Loose, sandy till also referred to as ablation till

Compact Till (Lodgement/Basal)

Compact or lodgement till is sediment that has been deposited by plastering of glacial debris on the land surface from a sliding glacier bed.

Characteristics:
1. Wide particle size distribution: clay, silt, sand, gravel, cobbles, stones and boulders
2. Unsorted, heterogeneous mixture
3. Angular shaped rock fragments
4. Substratum, firm and compact (locally referred to as hardpan)
5. Relatively high percent clay (7 - 25%)

Associated Landforms:
1. Drumlin
2. Till ridge
3. Ground moraine

Focus of On-Site Investigation:

1. Verify presence of compact substratum. Field method for identifying compact till:
    a. Note the ease of excavation by backhoe, a bucket often chatters across surface of compact till making shallow cuts with each pass.
    b. Pick at the side of a test hole with a knife to feel for ease of penetration.
    c. Squeeze a clod of soil between your thumb and index finger, initially compact till will resist crushing and then with increased pressure rupture suddenly.
2. Conduct percolation test in the most limiting layer.
3. Check for the presence of a perched water table
4. Avoid construction during wet periods, may cause soil smearing and compaction
5. If several areas fail to perc and one passes, determine the extent of suitable material

Sandy Loose Till (Ablation)

Ablation till was released by melting of stagnant or slowly moving debris-rich glacier ice and deposited without subsequent transport or deformation.

Characteristics:
1. Coarse textured, sandy, gravelly and stony
2. Typically loose, permeable material
3. VARIABLE, often has lenses or pockets of many stones and boulders
4. Small but significant amount of silt and clay

Associated Landforms:
1. Moraines: terminal and recessional
2. Ground moraine

Focus of On-Site Investigations

1. Determine variability and extent of soil conditions
2. Document any restrictive layers
3. Avoid construction during wet periods, smearing and compaction

GLACIAL OUTWASH

Definition: Stratified deposits of sands and gravel deposited by melt-water streams that flowed from melting glaciers.

Kinds: Two broad groupings of outwash:

1. Proglacial outwash - stratified outwash deposited in front of or just beyond the outer limits of a glacier
2. Ice-contact outwash - sands and gravel originally deposited adjacent to stagnant glacial ice that collapsed when melted leaving an irregular, often hilly terrain.

Proglacial outwash

Characteristics:

1. Stratified, well sorted material
2. Clean sands and gravel, typically with very little silt and clay
3. If present, gravel and cobble size rock fragments are rounded or sub-rounded
4. Loose material, walls of pit slough in
5. Generally lacks stones and boulders

Associated Landforms:

1. outwash plain

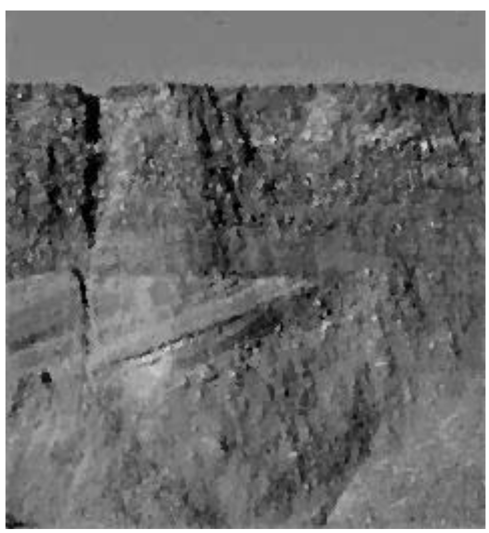


Figure 2-2. Proglacial outwash deposited by glacial meltwater streams

Focus of On-Site Investigation:

1. Rapid to very rapid percolation rates

CAUTION - if areas of these soils are extensive and thick, they are groundwater recharge areas and may be underlain by aquifers. If a site is identified as being within an important natural resource area, additional testing may be needed to assess the threat of possible increased nitrate and phosphorus levels on groundwater quality

2. Conduct percolation test in the most limiting layer.

Ice-Contact Outwash

Figure 2-3. Ice contact outwash showing changing conditions over short distances as a result of stream flow deposition from melting glaciers

Characteristics:

1. Variable - conditions change over short distances, very difficult to predict
2. Collapsed or slumped bedding
3. Well sorted to poorly sorted debris
4. Typically loose, sandy material but may include pockets or lenses of silty material
5. Dirty feel, often contains *significant* amounts of silt and clay
6. May include areas of stone and boulders

Associated Landforms (See Figure 2-4):

1. Kames -
2. Kame deltas
3. Kame terraces
4. Kettles
5. Eskers

Focus of On-Site Investigations:

1. Determine variability and extent of soil conditions
2. Document any restrictive layers

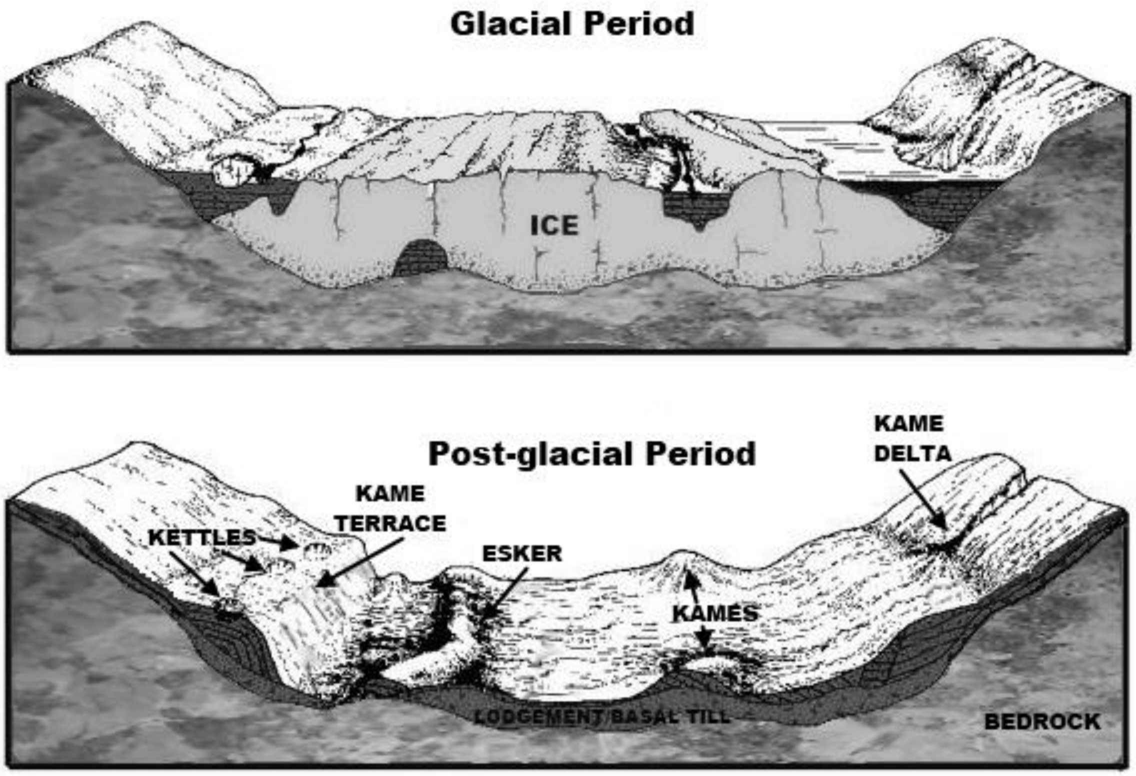


Figure 2-4. Landforms associated with post-glacial period

LACUSTRINE (lakebed) DEPOSITS

Definition: Well sorted, fine textured sediments deposited originally at the bottom of glacial lakes, which have since drained.

Figure 2-5. Example of lacustrine deposits showing alternating layers (varves) representing annual deposition in a glacial lake

Characteristics:

1. Well sorted, fine textured sediments
2. Generally high *content* of silt and/or clay

3. Rock fragments of gravel size and larger are typically absent

Associated Landforms:

1. Typically an undulating to rolling terrain and may have steep graded escarpments adjacent to water courses.

Focus of On-Site Investigation:

1. Typically slow to very slow perc rates
2. Check for vertical cracks in soils that may give erroneous perc rates
3. Very susceptible to smearing during wet periods
4. Poor internal drainage often causes these areas to be wet and have high seasonal water tables
5. Variable in some areas, particularly in old shoreline areas
6. Typically have thin layers of alternating silt and clay (varved) with the substratum.

MARINE SILTS and CLAYS

Definition: Areas of silts and clays deposited within a marine environment and have since been uplifted above present sea levels.

Figure 2-6. Example of marine silts and clays

Characteristics:

1. Limited extent, only occurring in the Boston area and north, and only in those towns close to the coastline
2. VARIABLE - typically well sorted soils high in silts and clays
3. Locally referred to as **blue clay**

Associated Landforms:

1. Typically an undulating to rolling terrain, locally associated with land areas below certain elevations

Focus of On-Site Investigation:

1. Typically have slow to very slow perc rates
2. Very susceptible to smearing during wet periods
3. Poor internal drainage causes these areas to be wet and have high seasonal water tables
4. Variable within some areas

COASTAL DUNE DEPOSITS

Definition: A natural hill, mound or ridge of sediment landward of a coastal beach deposited by wind action or storm overwash.

Characteristics:

1. Fine to coarse sands
2. Well sorted, often finely stratified
3. Little or no silt and clay, typically no gravel size or coarser rock fragments

Associated Landforms:

1. Ridges that often parallel the shoreline landward of the beach
2. Hills or mounds
3. Often have unvegetated areas of loose sand

Focus of On-Site Investigation:

1. Ever-changing landscape, susceptible to coastal erosion by wave action and strong winds
2. A protected resource area, CAUTION - check reference materials to determine extent of area

FLOODPLAIN (ALLUVIAL) DEPOSITS

Definition: Material transported and deposited by present day streams and rivers.

Characteristics:

1. Susceptible to seasonal flooding
2. Nearly level areas adjacent to large streams and rivers
3. Well sorted, often stratified
4. Fine textured, but may vary depending upon the velocity of the water
5. May have dark buried layers within the substratum that were at one time surface layers

Associated Landforms:

1. Floodplain
2. Stream terrace
3. Oxbow
4. Meander scar

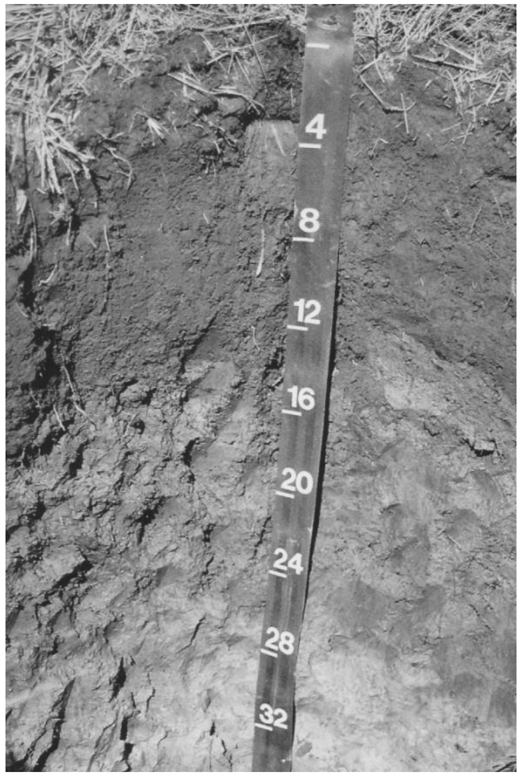


Figure 2-7. Example of a poorly-drained soil formed in a silty alluvial deposit on a modern-day floodplain (Limerick Soil).

SHALLOW-TO-BEDROCK AREAS

Shallow-to-bedrock areas are not soil parent material but their characteristics should be taken into consideration when attempting to locate an on-site sewage disposal system. Shallow-to-bedrock areas are associated with irregular terrain, steep ridges and abrupt knobs. Some areas are nearly level to gently rolling with few outcrops of ledge. Depth to bedrock can vary over short distances with variable complex conditions producing pockets of deep soil and areas of shallow to bedrock soils within short distances.

Characteristics:

1. Variable, complex soil conditions, typically pockets of deep soil and areas of shallow to bedrock soils
2. Depth to bedrock often varies over short distances
3. Weathered or fractured bedrock can often be excavated easily but is not considered suitable material for a leaching facility
4. Rippable or non-rippable with an excavator

Associated Landforms:

1. Bedrock areas are not associated with any particular landforms
2. Typically bedrock areas are associated with irregular terrain, steep ridges and abrupt knobs
3. Some areas of bedrock are nearly level to gently rolling with few outcrops of ledge

Focus of On-Site Investigation:

1. Due to variable site conditions, the deep hole should be located in the exact location of the proposed facility
2. Maintain 4-foot separation of suitable soil material between leaching facility and bedrock surface
3. Fractured bedrock is not considered a suitable soil material and the depth to bedrock is the upper surface of the fractured zone.

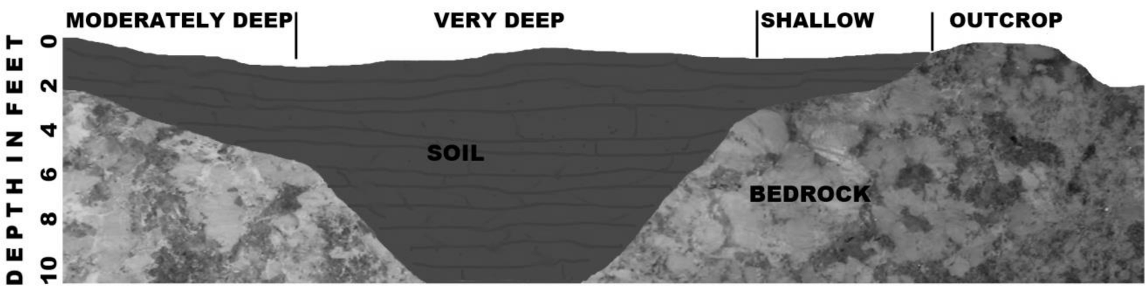


Figure 2-8. Profile of shallow-to-Bedrock area

SOIL HORIZONS AND LAYERS

Soil horizons and/or layers are strata within the soil that typically parallel the ground surface. They may differ from one another by color, feel, texture, presence of rock fragments, etc. The term “soil horizon” usually refers to strata that have been produced by soil-forming processes while soil layers have not (parent material). There are six major distinctions used to designate horizons and layers in the soil: O, A, E and B horizons, and C and R layers. The term “soil profile” refers to a vertical section of soil from the ground surface to the parent material.

Soil horizons are designated by a combination of:
CAPITAL LETTERS - lower case letters - ARABIC NUMERALS

Master Horizons and Layers: Major breaks in the soil: O, A, E, B, C, and R.

Subordinate Distinctions: Lower case letters used as suffixes to designate specific master horizons, i.e. Ap, Bw, Cd.

Vertical Subdivisions: A horizon designated by a single combination of letters which needs to be subdivided, i.e. Bwl, Bw2, Cdl, Cd2.

O- HORIZONS are soil layers with a high percentage of organic matter. Typically within a woodland area there are three distinct organic layers: one of leaves, pine needles and twigs (Oi); underlain by a partially decomposed layer (Oe); and then a very dark layer of well decomposed humus (Oa) .

Field Criteria:

- greater than 20-30% organic matter.
- dark, nearly black, color; colors can be misleading and should only be used when other field criteria are observed.
- low strength, greasy feel, light weight when dry, may have a high fiber content.
- typically a very dark surface horizon. When observed buried beneath a mineral horizon, this may signify a disturbed site where the original soil was buried by fill material.

A-HORIZONS are commonly referred to as the topsoil and typically ranges from 3 to 10 inches thick. They are mineral horizons that formed at the surface or below an O-horizon, and is characterized by humified organic matter intimately mixed with the mineral fraction. See Figures 3-1 and 3-3.

Field Criteria:

- a dark, surface, mineral horizon; characteristically darker than underlying horizons due to a relatively high organic matter content.
- mixture of well decomposed organic matter and mineral material.

Formation: Accumulation of organic matter under either saturated conditions (e.g. in marshes and bogs), or under aerated conditions where organic matter decomposition of the leaf litter (mineralization) is not an instant process.

E-HORIZONS are mineral horizons in the upper part of the soil. Typically present only in forested areas, the E-horizon underlies an O- or A-horizon. E-horizons are light colored, leached horizons. E-horizons are uncommon to many areas of Massachusetts and are most prominent within southeastern and northwestern portions of the state**.** See Figure 3-2.

Field Criteria:

- commonly near the surface, underlying an O or A-horizon and above a B-horizon.
- generally lighter in color than either the overlaying organic and/or A-horizons and the underlying B-horizon.

Formation: weak organic acids strip coating from the sand grains and material is leached down into the subsoil. The light color of the E-horizon is due to the natural color of the dominant quartz sand grains.

B-HORIZONS are commonly referred to as the subsoil. They are a zone of accumulation where rainwater percolating through the soil has leached material from above and it has precipitated within the B-horizons or the material may have weathered in place. Well-drained soils typically have the brightest color development within the B-horizon. See Figures 3-1, 3-2 and 3-3.

Field Criteria:

- subsurface horizon formed below an O, A and/or E-horizon and above the C-layer.
- in well-drained soils, the B-horizon is typically a yellowish brown to strong brown color and is commonly referred to as the subsoil.
- within Massachusetts, B-horizons typically extend to a depth of 2 to 3 feet.

C-LAYERS are commonly referred to as the substratum. These layers, excluding bedrock, are little affected by soil forming processes and have changed very little, if any, since the time they were deposited. See Figures 3-1, 3-2 and 3-3.

Field Criteria:

- little affected by soil forming processes.
- lack color development, color is that of the un-weathered geologic material.
- geologic layering or strata is often present.
- often, but not always, is the geologic material in which the overlaying soil developed.

R-LAYERS are hard bedrock (ledge).

Field Criteria:

- typically cannot be excavated using a backhoe unless fractured and blasting is often needed to remove this material.
- when highly fractured and/or weathered it is often difficult to differentiate from the overlaying soil material.
- may be difficult to differentiate between large boulders and depth to bedrock.

EXAMPLES OF SOME COMMON NEW ENGLAND SOIL PROFILES

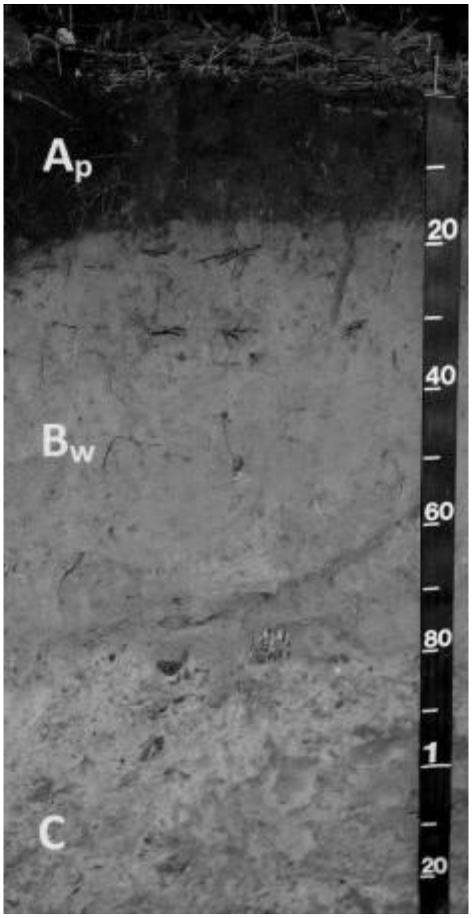


Figure 3-1

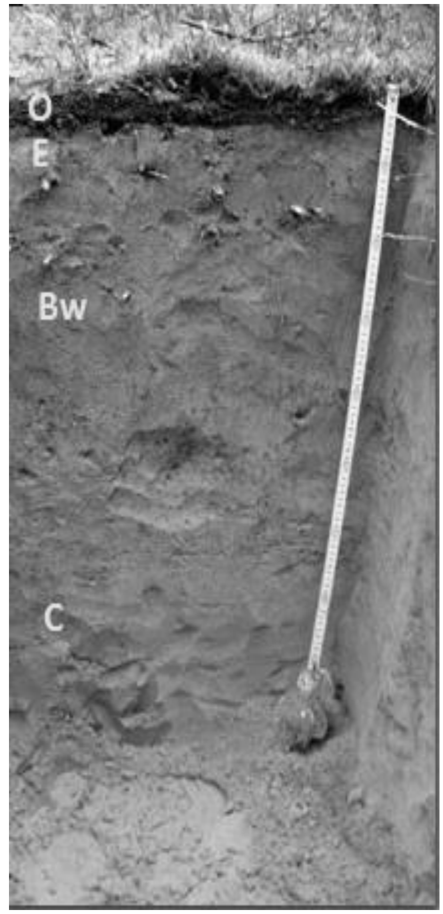


Figure 3-2

Figure 3-3

SOIL HORIZON AND LAYER DESIGNATIONS (SUMMARY)

ORGANIC HORIZONS

O-HORIZON: Layers dominated by organic material.

HORIZONS AND LAYERS IN MINERAL SOILS

A-HORIZON: Generally referred to as topsoil and typically ranging from 3 to 10 inches thick. Mineral horizon formed at the surface or below an O-horizon. Characterized by an accumulation of humified organic matter intimately mixed with the mineral fraction.

Subordinate Distinctions of A-Horizons:

Ap: plowed or other disturbance (commonly seen in Massachusetts soils).
Ab: buried horizon

E-HORIZON: Mineral horizon in the upper part of the soil, typically underlying an O or A horizon. Light colored, leached horizon ranging from not being present to 4 inches thick (you will not see an E-Horizon in the majority of test pits in Massachusetts).

B-HORIZON: Generally referred to as **subsoil**. The zone of accumulation within the soil. In well-drained soils it has the brightest colors. May extend 2 to 3 feet below the surface.

Subordinate Distinctions of B-Horizons:

- Bt- illuvial accumulation of clay.
- Bh - illuvial accumulation of organic matter (humus).
- Bs- illuvial accumulation of sesquioxides (iron and aluminum).
- Bhs - illuvial accumulation of both organic matter and sesquioxides.
- Bw - development of color or structure (commonly seen in Massachusetts soils).

C-LAYER: Generally referred to as **substratum**. These layers are little affected by soil forming processes (un-weathered geologic material).

Subordinate Distinctions of C-Layers:

Cd - dense unconsolidated sediment, used to designate compact glacial till.
Cg - strong gleying, indicates prolonged periods of saturation.
Cr - weathered or soft bedrock.

R-LAYER: Hard bedrock.

REFERENCE MATERIALS

FORM 11

MassDEP website:

Go to: http://Mass.gov/dep/ which is the MassDEP homepage and use the Search feature. For Form 11, type in "Title 5 Form 11" and then open up "Title 5 Septic System Forms" which should be the first link, then "Title 5 Construction & Repair Forms". Open the Form 11 Word document (not the PDF document because that one is old). For the Percolation Test form, type in "Form 12" and go to the same tabs as above with Form 11.

OR DIRECTLY USE THESE TWO LINKS:
Soil Suitability Assessment for On-Site Sewage Disposal - Form 11:
http://www.mass.gov/eea/docs/dep/water/approvals/year-thru-alpha/t-thru-v/t5form11.doc
Percolation Test - Form 12:
http://www.mass.gov/eea/docs/dep/water/approvals/year-thru-alpha/t-thru-v/t5form12.doc

SOIL SURVEYS

University of California at Davis soils mapping website:

http://casoilresource.lawr.ucdavis.edu

1. Click "Soil Survey"
2. Click "SoilWeb"
3. Go to "Menu" tab at upper left hand side of page where you can go to "Map Settings" and "Zoom to Location"
4. Click on your site area and soils information pops up on left hand side of page
5. Click on "Soil Type" for more information including soil series, soil profile, parent material, etc.

NE Soil website:

http://nesoil.com

Private site where you can connect to the U. of California-Davis soils mapping website. This site contains other soil information and photos of actual soil profiles. Once on, click on the "Soil Maps Google Maps" phrase on the right hand side of the page.

Web Soil Survey website:

http://websoilsurvey.nrcs.usda.gov

1. Click the green "Start WSS" button & go to the "Address" tab located under "Quick Navigation." Then type in the address in order to determine your area of interest. Once there, use the AOI tab above map to determine the exact area.
2. Once determined, click on the "Soil Map" tab to populate the soil information.
3. Then go to the "Soil Data Explorer" tab to get other information.
4. Click on the soil unit where you think your test pit will be located to get information on that particular map unit.
5. For more soils data while in the "Soil Data Explorer" tab, go to the "Soil Properties and Qualities" sub tab and explore there.

SURFICIAL GEOLOGY

The Massachusetts Geological Survey – Office of the State Geologist website:
http://mgs.geo.umass.edu/ - Home page

In order to locate your site in the correct quadrangle map, click on "New Surficial Materials Maps of Massachusetts Released." Click on the publication link and there is where you will find an "Index Map" of Massachusetts with all the quadrangle maps located on it. You can also open up each map from the site by clicking on the "Individual Quadrangle map Sheets" link, as well as download all 189 quadrangle surficial geologic maps by clicking on the "Maps of Quadrangles 1-189" zip file. Another way from the home page is to:

1. Select "USGS Surficial Geology Compilations."
2. Select the Area you want to view (Area A, area B, etc.). Once you select an area, a text page will appear.
3. Click on "quadrangle maps" highlighted in blue at the bottom of the Abstract paragraph. That will take you to a page where you can select the desired quadrangle. For an explanation of the colored mapped units, click on the "explanatory text" link found in the same abstract section as the quadrangle map's link is found.

For access to earlier scanned surficial geologic maps which may provide additional information, from the home page click on the "Maps/Data/Pubs/Links" tab, click on "Maps, Data & Publications," click on "Surficial Maps (NGMDB)," then click on "refine search." Under the "Themes" category, pull down the "Geology" menu and check "Surficial." Then go to the "State or Territory" box and click on "Massachusetts." Then below that, select the county to narrow your search of publications. Click the "search" button and all the surficial geology reports for that county will appear. Choose the correct quadrangle surficial map link for your site. use the following link: You can also simply use the link http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html and click on "Map Catalog" to get you to the Themes/State/County categories outlined above.

TOPOGRAPHIC AND ORTHOPHOTO MAPS, FLOOD ZONES, WETLANDS, SOURCE PROTECTION AREAS, ETC.

MassGIS:
http://maps.massgis.state.ma.us/map_ol/oliver.php

OR

1. Go to Mass.gov
2. In search bar, type in "MassGIS Oliver" and hit enter
3. Click on "online mapping" on the left side of the page
4. Click on "Oliver" to get into the map

From this point, or by simply going to the website above, one can add datalayers from the right hand side of the page after zooming to the site location.

IMPORTANT DATALAYERS:

- **IMAGES FOLDER** – USGS Topographic Maps Folder (choose USGS topographic maps layer and click on the USGS Topographic Maps layer); Aerial Photos Ortho Imagery Folder (choose Google 2018 Orthoimagery first. If nothing shows up, go to the next oldest imagery orthos because they may not have the latest orthos for that particular area). Some orthophotos are better viewed than others so open a few to see which works best.

- **PHYSICAL RESOURCES FOLDER** – Aquifers Folder (Aquifers by yield green shade and Sole Source Aquifer layers); Hydrography Water Features Folder (DEP Wetlands folder – choose the datalayer that works best; USGS 25K Rivers and Water Bodies Folder – add rivers streams and water bodies); Public Water Supplies Folder (Public Water Supplies layer); Surficial Geology Folder (general information – use State Geologists surficial maps before using these) - can get surficial deposit depths here
- **REGULATED AREAS FOLDER** – FEMA Flood Data (most current) Folder (FEMA National Flood hazard Layer polygons); Surface Water protection Areas Folder (Zone A); Wellhead Protection Areas Folder (IWPAs and Zone II layers)
- **Other folders are available, so explore and see which ones help you better evaluate your site**

CURRENT WATER RESOURCES CONDITIONS

United States Geologic Survey (USGS) Website:
For groundwater data measured from wells throughout Massachusetts, including Real-Time and monthly manual measurements, open this link:

https://groundwaterwatch.usgs.gov/NetMapT1L2.asp?ncd=crn&sc=25

A map of Massachusetts wells in their Climate Response network will load up. Click on any well and then the station number to get current and historical information.

You can also google “USGS climate response network” which will take you to the national map which you can zoom in on Massachusetts for the same map.

OTHER REFERENCES

You can access the **MassDEP well driller database** through a recently developed application in the EEA data portal. This application contains all but a few of the wells that MassDEP has in its possession.

Well information: https://eeaonline.eea.state.ma.us/portal#!/search/welldrilling

Addresses and phone numbers of MassDEP offices across the Commonwealth:
http://www.mass.gov/eea/agencies/massdep/about/contacts/

SOIL TEXTURE

Soil texture refers to the relative proportion of sand, silt, and clay in a soil. There are many different systems describing and classifying soil texture. These systems differ depending on their intended use. There are several standard systems, including USDA, UNIFIED, AASHTO, and FAA. Each breaks the soil up into different size fractions for specific use interpretations. When describing soils, it must be stated which system is being used. For example, "clay" could be soil less than 0.002 mm, 0.005 mm, or gray sticky stuff. For Title 5 purposes, the USDA system will be emphasized since it is the most widely used for describing, classifying and mapping soils; and is applicable to a wide range of uses.

In the USDA system, soil texture refers specifically to the relative proportion of the sand particles (2.0 mm - 0.05 mm), silt particles (0.05 mm - 0.002 mm) and clay particles (smaller than 0.002 mm) in the soil mass.

Sand particles can be seen with the naked eye and have a gritty feel to the fingers. These particles can easily be wiped clean from one's hands leaving no material in the pores of the hand. Dry sand particles are single grained and loose. The sand size particles can be subdivided into the following five classes:

very coarse sand:	2.00 - 1.00 mm
coarse sand:	1.00 - 0.50 mm
medium sand:	0.50 - 0.25 mm
fine sand:	0.25 - 0.10 mm
very fine sand:	0.10 - 0.05 mm

Silt size particles can be seen only with a hand lens or light microscope. They have a smooth powdery feel when dry and a slick creamy feel when moist or wet. Silt is non-sticky and non-plastic. After handling silty soil samples a film will be left on one's hands, which for the most part can be wiped off when dry, leaving silt particles only in the pores of the hand.

Clay size particles can only be seen with an electron microscope. Clay is sticky and plastic when wet, and hard to very hard when dry. After handling clayey samples a film will be left on the hands and only be removed by scrubbing.

Rock fragments are particles larger than sand size and common in many New England soils. They are classified by their size into:

gravel:	2 mm to 3 inches
cobbles:	3 to 10 inches
stones:	10 inches to 2.5 feet
boulders:	greater than 2.5 feet in diameter

Soil Textural Classes

Rarely in nature do soils consist entirely of one size particle; meaning all sand, all silt or all clay. Generally, soils are a combination or mixture of different particle sizes. These different combinations are referred to as textural classes. There are many different textural classes. The basic textural classes usually encountered in Massachusetts in order of increasingly finer texture are: sand, loamy sand, sandy loam, loam, silt loam, silt, silty clay loam, and silty clay. Loam is a term that has many, often conflicting, meanings. The common meaning is that of a dark, fertile topsoil. In the USDA textural classification system loam refers only to the sand, silt and clay size particles; and is a soil with a significant amount of all three particle sizes.

Textural class names provide a basis for making predictions of soil behavior. Although texture is probably the most important single characteristic used to predict soil behavior, other soil properties such as structure and consistence must be considered before an accurate judgment can be made. Soil texture is a primary consideration for predicting hydraulic conductivity, bulk density, water holding capacity, shrink-swell potential, frost action, subsidence, bearing capacity, compactibility, infiltration rate, erodibility, and more.

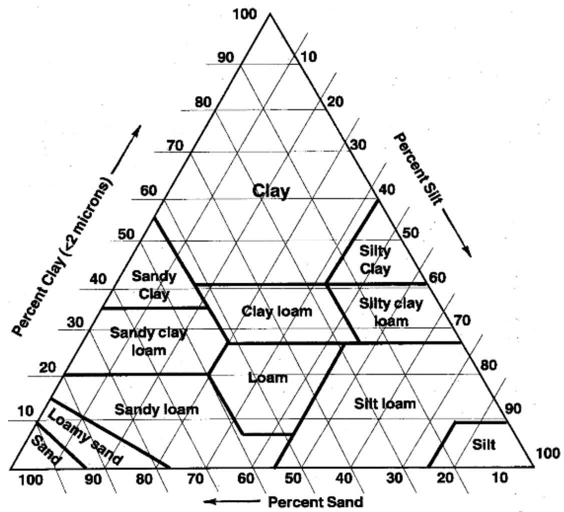


Figure 5-1

Textural Triangle

The textural triangles (Figure 5-1) show the 12 basic soil textural classes and associated percentages of clay (less than 0.002 mm), silt (0-002 to 0.05 mm), and sand (0.05 to 2.0 mm). The textural triangle is used when laboratory data are available. Plot the percent sand using the bottom of the triangle, silt using the right side, and clay the left. **Caution:** plot percentages following the angle of the numbers on each side of the triangle.

Field Method for Determining Soil Textural Class

Figure 5-2

Sample Preparation:

- place a tablespoon of representative soil sample in the palm of your hand (see Figure 5-3.)
- separate out and remove all particles greater than 2 mm in size, about the diameter of lead in a wooden pencil.
- wet the sample and rub vigorously to break up any aggregates or clods of dry soil.

Figure 5-3

Soil samples that are comprised predominantly of sand size particles versus soil samples that are predominantly silt and/or clay size particles (see Figure 5-3):

- with the wet soil sample in the palm of your hand, rub and stir with a finger from the opposite hand.
- soils with more than 50 percent sand size fraction, have a gritty to very gritty feel.
- soils that have a smooth creamy feel with little to no grittiness, are high in silt and/or clay.

Soils with more than 50 percent sand sized particles:

- Soil textural classes for soils with more than 50 percent sand sized particles include sands, loamy sands, and sandy loams.
- The field test used to differentiate these three textural classes is to make a cast and estimate its durability. To make a cast take a fresh, moist (not too wet or too dry) sample from the test pit. The moisture condition of the sample is critical when doing this test. A dry sample will not form a cast and a wet sample will almost always form a cast. Place a table-spoon sized sample of moist soil in the palm of your hand and firmly press the sample together with the fingers of the opposite hand, creating a rough ball-shaped soil cast (see Figure 5-4).

Figure 5-4

Sand textural class (greater than 85% sand) will either not form a cast or will form a cast that crumbles with slight handling.
Loamy sand textural class (70 to 85% sand) will form a cast which bears only slight to moderate handling before falling apart.
Sandy loam textural class(50 to 70% sand) will form a cast, which will withstand moderate handling and retain its shape.

Soils with more than 50 percent silt and/or clay sized particles:

- The field tests used for differentiating soils that are high in silt from those that have a significant clay content (greater than 30%) are the tests for stickiness and plasticity.
- Moisture content is critical when doing either test. The moisture content that makes the sample the stickiest or most plastic is the one to use. Gradually add moisture to a tablespoon-size sample of soil, while mixing in the palm of one's hand.
- Stickiness test: squeeze a very moist soil sample between your thumb and index finger and then pull apart. Soil material that is very high in silt is non-sticky and the sample will adhere to either the thumb or finger and separate cleanly from the other. A soil with a significant amount of clay (greater than 30%) will initially stretch between the thumb and finger, and then pull apart with some soil adhering to both the thumb and the finger (silty clay texture). (See Figures 5-5a and 5-5b).

Figure 5-5a

Figure 5-5b

- **Plasticity test**: There are two procedures for doing this test, forming a ribbon or making a wire. The ribbon test is done by pinching and pushing a thin ribbon of sample out from beneath the thumb and over the top of the index finger. A soil sample high in silt and low in clay will form a short ribbon, typically less than 1.5 inches (silt loam texture). A soil significantly high in clay (more than 30%) will form a ribbon longer than 2 inches (silty clay texture). Another test for plasticity is to form a wire. A soil sample is rolled out into a wire by placing a very moist sample between one's palms and then moving them back and forth over one another. If a wire cracks or breaks before it reaches 1/8 inch in diameter, the sample is high in silt with a small clay fraction (silt loam texture). If a wire less than 1/8 inch in diameter is formed, a relatively high percent of clay is present (silty clay texture). (See Figures 5-6a and 5-6b.)

Figure 5-6a

Figure 5-6b

NOTE: Very fine sandy loam and loam textural classes typically have the feel of both sandy and silty soils. If you are having difficulty deciding on what direction to take above, you may want to consider either of these textural classes. Loam, when dry, can be crushed under moderate pressure and when pulverized has a velvety feel. Loam when moist may have a very slight tendency to ribbon. Very fine sandy loam textures when thoroughly wetted will have a very slightly gritty sensation when rubbed in one's palm.

TEXTURAL CLASS MODIFIERS

Coarse Fragments: If a soil sample has between 15 to 35 percent by volume of coarse fragments (greater than 2 mm in diameter), a textural modifier is used, for example gravelly sandy loam.
If a soil sample has between 35 percent and 60 percent by volume of coarse fragments, a textural

modifier is used, for example a very gravelly sandy loam. If the soil sample contains more than 60 percent by volume the modifier is "extremely", e.g. extremely gravelly sandy loam.

Organic Matter: If a soil has a significant volume of organic matter (10 to 20% by weight), a textural modifier is used, for example a mucky sandy loam.

GRADATION CURVES

The results of a mechanical analysis are frequently plotted in the form of a gradation curve. A well-graded soil has a little bit of every grain size, whereas a uniform soil indicates sorting by either wind, water or a sieve to result in a material in which all particles are more or less the same size. Many sand filters and fill materials require a fairly uniform grain size. A sample's uniformity is expressed by the uniformity coefficient (U_c defined as D_{60}/D_{10}).

To calculate the U_c of a soil material, plot the gradation curve. Draw a horizontal line starting at the 60% passing point on the left axis. At the intersect with the gradation curve draw a vertical line down to obtain the grain size at which 60% is passing. Repeat this procedure for the 10% passing point. Dividing the size value at D_{10} into the size value at D_{60} results in the U_c.

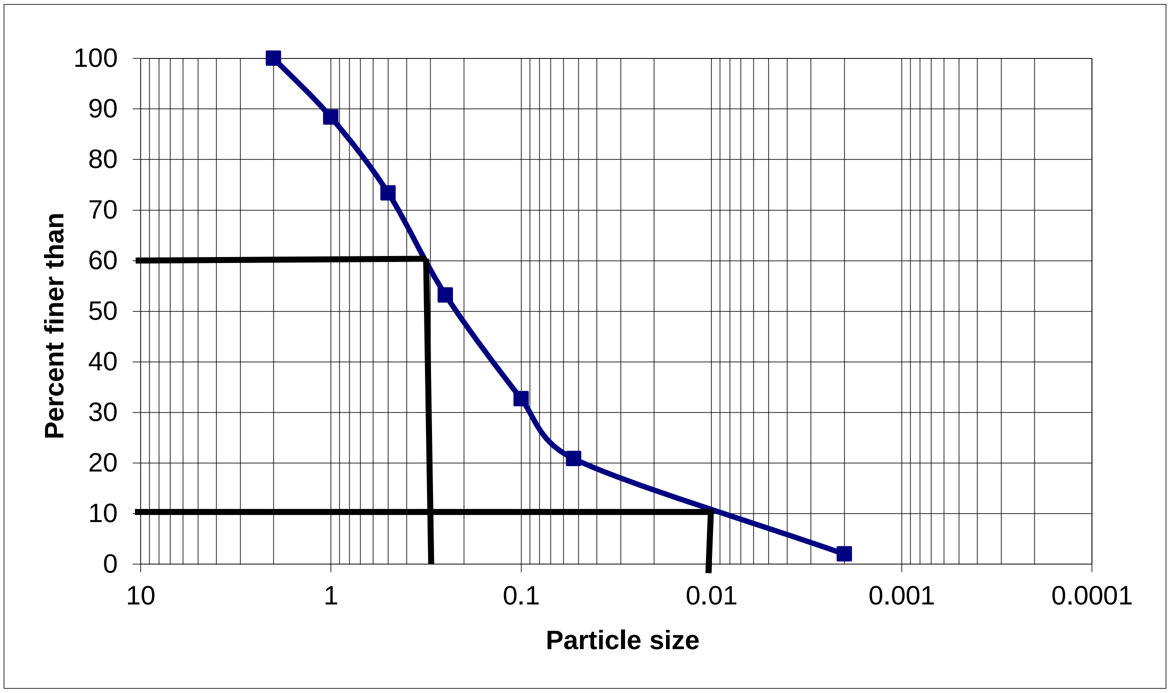


Figure 5-7: Textural Analysis - Grain diameter in millimeters

The suitability of a fill material can easily be assessed in the field using a 1-quart mason jar and *Cascade.* Put enough soil in the jar to cover the bottom. Add a very small amount of the *Cascade* (just a knife tip is fine) and add sufficient water to cover the soil. Occasionally swirl the jar gently. After 10 minutes, fill the jar with water and shake to uniformly distribute the soil material throughout the suspension. Let stand for about 10 minutes. A sample that remains cloudy probably has too many fines and its suitability should be questioned. If the water above the soil remains clear, the material is probably suitably as fill.

NOTE: Dissolved organic matter and iron sometimes also may cloud the water.

SOIL COLOR

Soil color is the most obvious and easily determined soil characteristic. Although it has little known direct influence on the functioning of the soil, color is one of the most easily determined soil properties and other more important soil characteristics can be inferred from soil color.

Munsell Color System

Soil colors are most conveniently measured by comparison with a color chart (Figure 6-1). The soil color charts consist of many different colored chips, systematically arranged according to their Munsell color notations.

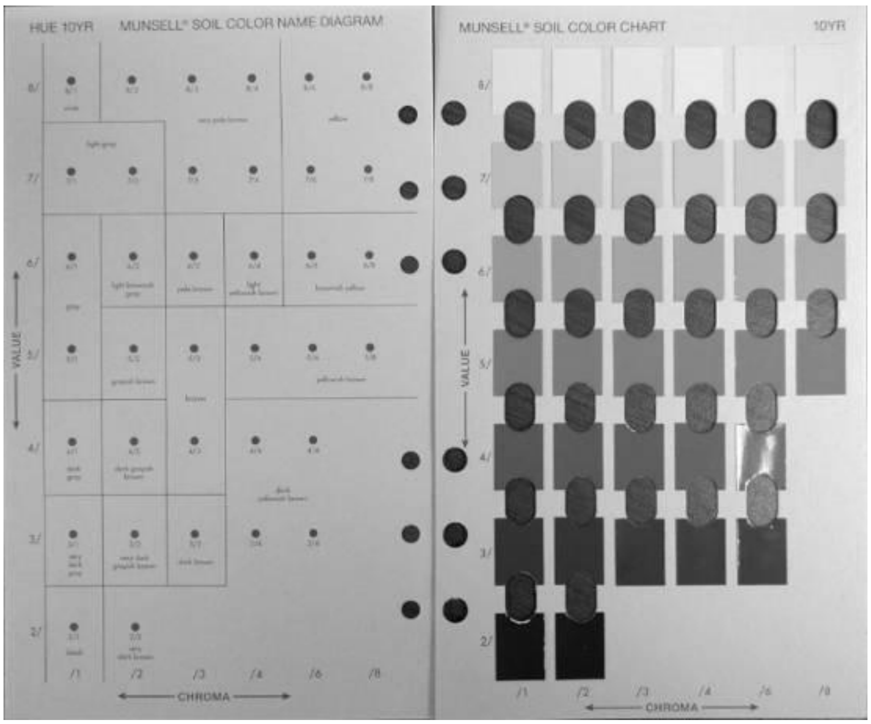


Figure 6-1. Example of a color page from the Munsell Color Charts

The Munsell notation for color consists of separate notations for **hue**, **value**, and **chroma**, which are combined in that order to form the color designation.

Hue refers to the dominant spectral wavelength of light (red, yellow, green, blue, etc.). The symbol for hue is the letter abbreviation of the color preceded by a number from 0 to 10. With the YR (yellow red) range, the hue becomes more yellow and less red as the number increases. The notation for hue in the *Munsell Soil Color Charts is* located at the top right corner of each individual color chart page. One hue is represented on each page. The *EarthColors* book gives the color notation directly under each color chip.

Value refers to the degree of lightness and darkness of a color in relation to the neutral gray scale. The notation for value consists of numbers from 0 (black) to 10 (white). In the *Munsell Soil Color Charts,* value is located along the left side of the color page and increases from bottom to top. Color chips in the *EarthColors* book are arranged in a similar fashion with the color notation written directly under each color chip.
Chroma is the relative purity or length of the hue. The notation for chroma consists of numbers beginning at 0 for neutral grays (no pigment added) and increasing at equal intervals to 8. In the *Munsell Soil Color Charts,* chroma is located along the bottom of the color page and increases from left to right.

Once a soil color determination is made, the proper notation of the color is the hue, followed by the value and chroma. Value is always written first followed by the chroma. An example of the correct notation of a soil color would be 1OYR 5/6 (hue of l0YR, value of 5, chroma of 6). The dominant color in the soil is called the matrix color. When soil colors are the result of oxidation and reduction (redox) processes on account of soil wetness we refer to these as redoximorphic features.

Field Method for Recording Soil Color

People's perception of color varies and it's not unusual for people to vary one color chip. The following conditions may affect the accuracy of the color determination.

Moisture conditions: The moisture content (wet, moist, dry) of the soil has a bearing on the color of the soil. Moist color is the color most often recorded. It is typically the moisture condition of the soil when it is first removed from the pit. During periods that the soil is dry (summer and early fall, or during droughts) soil samples should be moistened with a gentle spray of water until the color is no longer affected by further additions of water. Be careful not to wet the soil too much (soil surface is glistening). Wet samples should be blotted with a paper towel.

Light conditions: Soil colors should be recorded under full light conditions. Interior lights generally do not provide a full spectrum light source, hence should not be used when determining soil color. Soil colors are recorded out-of-doors in indirect sunlight, typically sunlight from over your shoulder. When the sun is at a low angle either early morning, late afternoon or during the winter months; colors are difficult to read. *Note: Please don't forget to remove your sunglasses. Weather conditions, particularly dark overcast days affect color readings and should be noted on the soil log form.*

Location in soil: Colors are typically recorded for the surface of a freshly-broken clod of soil. Do not mix your sample prior to the color determination.

Multiple colors: If there is more than one color, determine which one is the matrix (dominant) color and which one is the color of the redoximorphic features. Estimate the percentage of the various redoximorphic features as well as their Munsell color notation.

COLOR PATTERNS IN THE SOIL

In a well-drained soil, the topsoil is typically a dark brown color underlain by a weathered yellowish brown to strong brown subsoil. The bright colors of the subsoil are the result of iron oxide stains coating the individual sand grains. With depth, the color of the subsoil gradually fades to the substratum. The color of the substratum is dependent on the mineralogy of the individual soil particles and may range from a light brownish gray (soils high in quartz) to a dark grayish brown color (soils high in dark minerals).

Coloring Agents in the Soil

- **Organic material** darkens the soil. As little as 2 to 5 percent can give the soil a dark brown to black color. It is a strong coloring agent and will mask all other coloring agents in the soil. Organic matter is typically associated with the surface layers and when it is observed below a mineral layer, it often indicates a disturbed site.
- **Iron** is the primary coloring agent in the subsoil. Iron bearing minerals are nearly universal in all New England soils. The bright orange-brown colors associated with upland soils is the result of iron oxide stains coating individual soil particles.
- **Manganese** is common in some New England soils and gives the soil a very dark, black or purplish black color.

In the absence of color coatings on soil particles, soils are the color of the mineral grains, often a grayish color due to the preponderance of quartz and feldspar minerals.

SOIL STRUCTURE AND CONSISTENCE

SOIL STRUCTURE

Soil structure refers to units composed of primary particles. The cohesion within these units is greater than the adhesion among units. As a consequence, under stress, the soil mass tends to rupture along predetermined planes or zones. These planes or zones, in turn, form the boundary. A structural unit that is the consequence of soil development is called a **ped**. The surfaces of peds persist through cycles of wetting and drying in place. Commonly, the surface of the ped and its interior differ as to co-position or organization, or both, because of soil development. **Clods** are structural units for which soil forming processes exert weak or no control on the boundaries. Some clods, adjacent to the surface of the body, exhibit some rearrangement of primary particles to a denser configuration through mechanical means (soil compaction). The same terms and criteria are used to describe peds and clods including shape, grade, and size.

Some soils lack structure and are referred to as structureless. In structureless layers or horizons, no units are observable in place or after the soil has been gently disturbed, such as by tapping a spade containing a slice of soil against a hard surface or dropping a large fragment on the ground. Structureless soil material may be either single grain or massive. Soil material of single grains lacks structure; in addition, it is loose. On rupture, more than 50 percent of the mass consists of discrete mineral particles. Some soils have simple structure, each unit being an entity without component smaller units. Others have compound structure, in which large units are composed of smaller units separated by persistent planes of weakness. In soils that have structure, the shape, size, and grade (distinctness) of the units are described. Field terminology for soil structure consists of separate sets of terms designating each of the three properties, which by combination form the names for structure (Figures 7-1 and 7-2).

- **Shape:** Several basic shapes of structural units are recognized in soils. Supplemental statements about the variations in shape of individual peds are needed in detailed description of some soils. The following terms and figure describe the basic shapes and related arrangements:

    - **Platy:** The units are flat and platelike. They are generally oriented horizontally. A special form, lenticular platy structure, is recognized for plates that are thickest in the middle and thin toward the edges.
    - **Prismatic:** The individual units are bounded by flat to rounded vertical faces. Units are distinctly longer vertically, and the faces are typically casts or molds of adjoining units. Vertices are angular or rounded; the tops of the prisms are somewhat indistinct and normally flat.
    - **Columnar:** The units are similar to prisms and are bounded by flat or slightly rounded vertical faces. The tops of columns, in contrast to those of prisms, are very distinct and normally rounded.
    - **Blocky:** The units are blocklike or polyhedral. They are bounded by flat or slightly rounded surfaces that are casts of the faces of surrounding peds. Typically, blocky structural units are nearly equidimensional but grade to prisms and to plates. The structure is described as angular blocky if the faces intersect at relatively sharp angles; as subangular blocky if the faces are a mixture of rounded and plane faces, and the corners are mostly rounded.
    - **Granular:** The units are approximately spherical or polyhedral and are bounded by curved or very irregular faces that are not casts of adjoining peds.
    - **Structureless:** Soils that have no structure are termed either **single grained** (individual sand grains) or **massive** (does not break apart into any specific shapes)

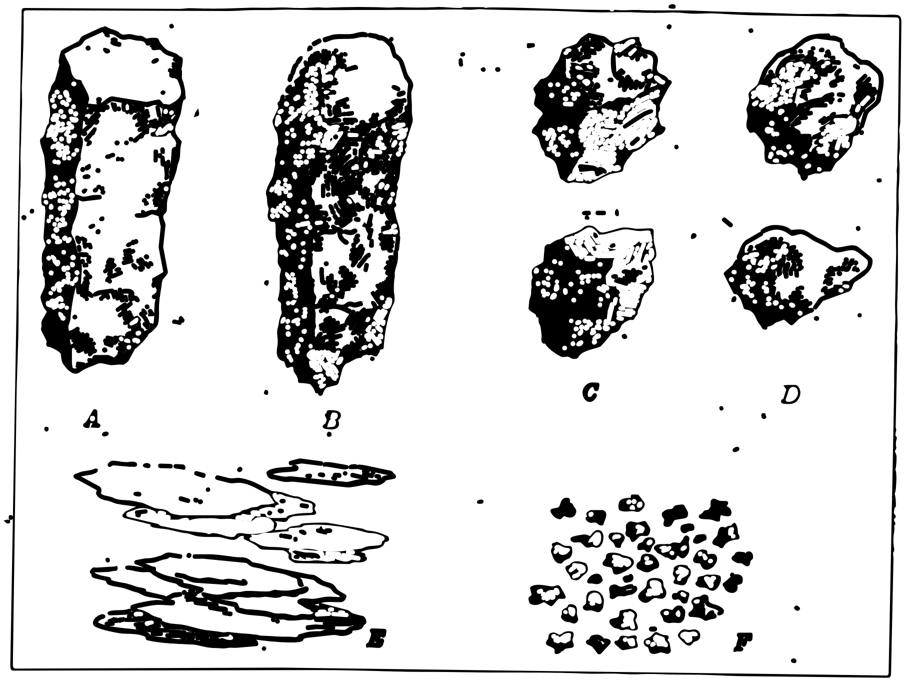


Figure 7-1: Different types of soil structure: A is prismatic, B is columnar, C is angular blocky, D is sub angular blocky, E is platy, and F represents granular structure.

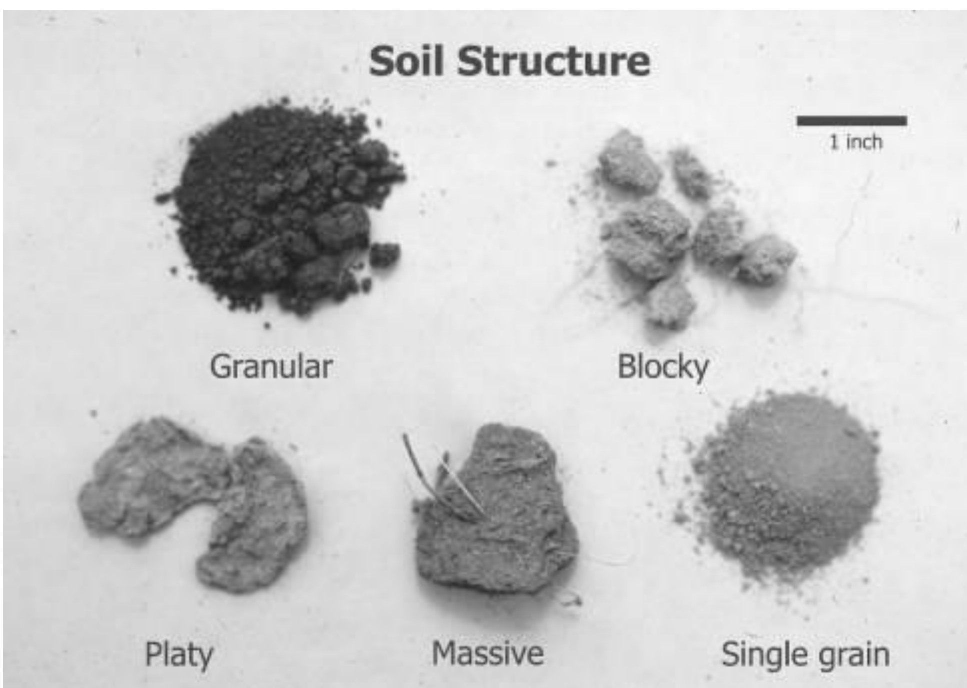


Figure 7-2: Soil samples with different types of soil structure

- **Size**: Five size classes are employed: very fine, fine, medium, coarse, and very coarse. The size limits of the classes differ according to the shape of the units. The size limit classes are given in the following table. The size limits refer to the smallest dimension of plates, prisms, and columns. If the units are more than twice the size of "very coarse," the actual size is given. The size of structural units is not used for basic soil evaluation.

	Structure/Shape			
	Platy	Prismatic	Blocky	Granular
Size Classes	mm			
Very fine	< 1	< 10	< 5	< 1
Fine	1-2	10- 20	5-10	1-2
Medium	2-5	20- 50	10-20	5-10
Coarse	5-10	50-100	20-50	5-10
Very coarse	> 10	> 100	>50	> 10

In describing plates, "thin" is used instead of "fine" and "thick" instead of "coarse."

- **Grade. Grade describes the distinctness of units.** Criteria are the ease of separation into discrete units and the proportion of units that hold together when the soil is handled. Three classes are used:

  Weak. The units are barely observable in place. When gently disturbed, the soil material parts into a mixture of whole and broken units and much material exhibits no planes of weakness. Faces that indicate persistence through wet-dry-wet cycles are evident if the soil is handled carefully. Distinguishing structurelessness from weak structure is sometimes difficult. Weakly expressed structural units in virtually all soil materials have surfaces that differ in some way from the interiors.

  Moderate. The units are well formed and evident in undisturbed soil. When disturbed, the soil material parts into a mixture of mostly whole units, some broken units, and material that is not in units. Peds part from adjoining peds to reveal nearly entire faces that have properties distinct from those of fractured surfaces.

  Strong. The units are distinct in undisturbed soil. They separate cleanly when the soil is disturbed. When removed, the soil material separates mainly into whole units. Peds have distinctive surface properties.

The three terms for soil structure are combined in the order (1) grade, (2) size, (3) shape. "Strong fine granular structure" is used to describe a soil that separates almost entirely into discrete units that are loosely packed, roughly spherical, and mostly between 1 and 2 mm in diameter.

- **Compound Structure** Smaller structural units may be held together to form larger units. Grade, size, and shape are given for both and the relationship of one set to the other is indicated: "strong medium blocks within moderate coarse prisms," or "moderate coarse prismatic structure parting to strong medium blocky. "

SOIL CONSISTENCE

Soil consistence in the general sense refers to "attributes of soil material as expressed in degree of cohesion and adhesion or in resistance to deformation on rupture. " Consistence includes: (1) resistance of soil material to rupture, (2) resistance to penetration, (3) plasticity, toughness, and stickiness of puddled soil material, and (4) the manner in which the soil material behaves when subject to compression. A similar term, consistency, was used originally in soil engineering for a set of classes of resistance to penetration by thumb or thumbnail (test designation D 2488, ASTM, 1984). The term has been generalized to cover about the same concept as "consistence." Consistence is highly dependent on the soil-water state and the description has little meaning unless the water state class is specified or is implied by the test. The consistence is described either in the dry or the moist state. When making soil descriptions in humid regions the soil-moisture state should be the moist condition. Consistence includes stickiness, plasticity, and toughness.

To evaluate the soil consistence, a block-like specimen, 25-30 mm on edge, is compressed between thumb and forefinger, between both hands, or between the foot and a non-resilient flat surface depending on the degree of resistance. If the specimen resists rupture by compression, a weight is dropped onto it from increasingly greater heights until rupture.

Unless specified otherwise, the soil-water state is assumed to be that indicated for the horizon or layer when described. Cementation is an exception. To test for cementation, a specimen is air dried and then submerged in water for at least 1 hour.

The following consistence (rupture resistance) classes for moist or wetter soils can be identified:

Class	**Test Description**
Loose	Specimen not obtainable.
Very friable	Fails under <u>very slight force</u> applied slowly between thumb and forefinger.
Friable	Fails under <u>slight force</u> applied slowly between thumb and forefinger.
Firm	Fails under <u>moderate force</u> applied slowly between thumb and forefinger.
Very firm	Fails under <u>strong force</u> applied slowly between thumb and forefinger.
Extremely firm	Cannot be failed between thumb and forefinger but can be failed between both hands or by placing on a non-resilient surface and applying a gentle force underfoot.
Slightly rigid	Cannot be failed in hands but can be underfoot by full body weight applied slowly.
Rigid	Cannot be failed underfoot by full body weight but can be by dropping a 3 kg weight 10 cm.
Very rigid	Cannot be failed by dropping a 3 kg weight 10 cm.

REDOXIMORPHIC FEATURES

In a soil with a fluctuating water table, there are two contrasting chemical environments. When the water table is high and the soil is saturated, there is a reducing environment within the soil (lack of free oxygen). When the water table is low, the soil is well aerated and oxygen moves freely through the open pore spaces in the soil.

Within this zone of a fluctuating water table, iron, the main color agent in the subsoil, takes on two different forms. When the soil is saturated, iron is reduced (ferrous state) and becomes mobile in the soil migrating from one area to another. Gray areas develop in the soil where the iron has been depleted. When the water table recedes, in areas where the iron has migrated and concentrated, the iron is oxidized (ferric state) and is less mobile in the soil developing bright colors of yellow, orange and/or red. Within this zone of a fluctuating water table, spots or blotches of color (redoximorphic features) are formed. Grey areas represent conditions where the iron has been reduced and flushed from the soil; whereas yellow, orange and/or red areas indicate iron accumulations. This blotchy pattern of both bright and dull colors is referred to as redoximorphic features and is interpreted by soil scientists as a zone in the soil with a fluctuating seasonal high water table.

Potential Problem Areas When Interpreting Redoximorphic Features

- Sandy soils. Redoximorphic features are often faint and difficult to differentiate from the matrix.
- Relic redoximorphic features. Redoximorphic features that formed in a wet soil which has since been drained, persist for years and do not represent the present hydrology.
- Stratified deposits: changes in soil texture may momentarily interrupt wetting fronts as they move downward through the soil. This brief pause is not considered a perched water table but may produce bright streaks or blotches at the interface. These are often seen within gravel pits, high above the water table.
- Parent material: some soils develop in dark sediments and may mask redoximorphic feature development.
- Soil chemistry: some soils have unique chemical properties that inhibit the development of redoximorphic features. Soils developed within Triassic Red Sandstone sediments and soils that are immediately adjacent to brackish water are examples of soils which do not develop easily recognizable redoximorphic features.
- Recently-deposited material: redoximorphic features typically develop slowly, often taking many years.

Describing Redoximorphic Features

A description of redoximorphic features requires a notation of the colors and of the color pattern. Colors should be noted using Munsell symbols for both the matrix and the redoximorphic features. The color pattern may be described using abundance, size and contrast. For Title 5 purposes we will only describe the color of the redoximorphic features and their abundance.

- **Abundance**: For Title 5 purposes a numerical estimate of the abundance of the redoximorphic features is required. Soil scientists when making routine profile descriptions use the following terminology:

Few:	features < 2 % of the surface	(f)
Common:	features 2 - 20% of surface	(c)
Many:	features > 20% of surface	(m)

- **Size**:

Fine:	< 5 mm	(1)
Medium:	5 – 15 mm	(2)
Coarse:	> 15 mm	(3)

- **Contrast:**

▪	Faint:	Hue and chroma of matrix and redoximorphic features closely related	(f)
▪	Distinct:	Matrix and redoximorphic features vary 1 to 2 hues and several units in chroma and value	(d)
▪	Prominent:	Matrix and redoximorphic features vary several units in hue, value, and chroma	(p)

DOCUMENTING SITE CONDITIONS

The actual determination of site conditions is the culmination of all the theory discussed so far. This section will describe the value of site evaluation, proper procedures for conducting deep observation hole examinations and percolation tests, proper soil log preparation, and how to put it all together to expedite final design and/or review.

See the MassDEP website for Form 11, Soil Suitability Assessment for On-site Sewage Disposal: http://www.mass.gov/eea/docs/dep/water/approvals/year-thru-alpha/t-thru-v/t5form11.doc

Value of Site Evaluation

Site evaluation is the first step in finalizing the design of an on-site sewage disposal system. It includes soil characterization, determination of maximum groundwater levels, percolation tests and identification of any special conditions that may exist on-site which could affect the design or performance of the sewage disposal system.

Historically, site evaluation has been accomplished through deep observation holes and percolation tests. The deep observation hole exposes the soil column for inspection and also allows for the determination of groundwater levels. Usually the soil profiles developed from observation holes are rather generic and the percolation rate is considered the overriding factor in governing design. However, regulatory changes to Title 5 recognize that not all percolation rates are created equal and that for a given percolation rate variations in soil type can dramatically affect the performance of the disposal system. As a result, it now becomes imperative that all site evaluators be able to accurately determine different soil types in order to ensure proper design of sewage disposal systems.

Proper analysis and characterization of the soil is, perhaps, the most critical element in the design of an on-site sewage disposal system. Soil provides the treatment matrix, controls the hydraulic acceptance of effluent, and can determine the success or failure of the system. Without a good initial evaluation of the site and soil, the disposal system may be doomed before it is ever put in the ground.

Preliminary Procedures

> Site evaluation should begin even before going out in the field. Office preparation can provide the site evaluator with valuable data which will make the actual site visit more productive, identify the areas most suitable for subsurface sewage disposal, and may preclude the specter of ugly and unwanted surprises.

At the very least, one should consult current soil survey maps, topographic and surficial geology maps (USGS quadrangles or locally prepared maps), and local records available from health department or building department files. These sources will aid in determining the types of soil likely to be encountered and the surficial relief characteristics of the site (i.e. level, sloping, moderately sloping or severely sloping). The site evaluator should also identify known special conditions encountered in the area. These would include the presence of high groundwater, wetlands, “tough” soils, etc. All this information will help in identifying areas on the site appropriate for testing so that field time may be utilized efficiently.

It is important for site evaluators to know the engineer or health agent with whom they will be working. Have you worked with them before? Do they have any special preferences or practices?

If encountering someone unfamiliar, it is always best to discuss procedures and objectives beforehand. The site visit will proceed smoothly if everyone is aware of the ground rules from the beginning.

PERCOLATION TEST

In Massachusetts, the percolation test traditionally has been the basis of design for subsurface sewage disposal systems. Essentially, it measures the rate at which clear water is transmitted through the soil in a twelve-inch-diameter by eighteen-inch-deep hole in order to determine the suitability of the soil to accept effluent at the leaching elevation and to a depth four feet below. Since Title 5 relies on the percolation test to determine loading rates, it is the most important aspect of the site evaluation in terms of the design of the sewage disposal system. However, the percolation rate itself has little correlation to the actual infiltration rate of the effluent and the loading rates determined from percolation test results are highly based on empirical data. The concept of the Long Term Acceptance Rate (LTAR) has gained wide acceptance in correlating percolation rates to design loading rates by taking into account such variables as soil type, biomat formation, moisture tension and other factors.

Title 5 requires that percolation tests be performed on the lot in all areas proposed for leaching, including the reserve area. Multiple tests may be required at the discretion of the approving authority when changes in the soil occur at various elevations within the hole or when changes in soil are noted across the lot. Multiple tests should also be required when the installation of a large leaching system is planned. Percolation test results can be reported using Form 12 (Percolation Test), which can be found at http://www.mass.gov/eea/docs/dep/water/approvals/year-thru-alpha/t-thru-v/t5form12.doc. Other forms may be utilized, but the information must be substantially the same as that required on Form 12.

> *Safety should always be the prime concern during any field testing. As a general rule, one should never enter a hole deeper than one's chest height unless proper precautions have been taken to ensure the stability of the excavation. Percolation tests should be performed on an excavated shelf that provides easy and safe access and egress. If the hole is deeper than chest height, the sides should be excavated at a minimum 3:1 slope or reinforced with trench boxes. Oftentimes we take safety for granted; however, if a hole caves in on a person it can be fatal.*

Title 5 describes the percolation-test procedure. It must be emphasized that this procedure must be diligently followed, as any deviations will drastically affect the percolation rate. Remember, consistency in applying the procedure is of paramount importance.

Percolation tests are to be performed as follows:

1. Prepare a test hole 12 inches in diameter and 18 inches deep into the proposed leaching strata within the disposal area.

2. Establish a fixed point at the top of the test hole from which all measurements can be taken.

3. Scratch the bottom and sides of the test hole to remove any smeared soil surfaces. Either add two inches of coarse sand to protect the bottom from scouring, or insert a board or other impervious object in the hole so that water may be poured down or on it during the filling operation.

4. Carefully fill the hole with clear water to a minimum elevation of 12 inches and maintain the water level by adding water as necessary for the purpose of soil saturation, but in no case less than fifteen minutes after first filling the hole.

5. After saturation, let the water level drop from a depth of 12 inches to a depth of 9 inches and then measure the length of time it takes for the water level to drop from a depth of 9 inches to a depth of 6 inches. If the rate is erratic, in the opinion of the approving authority, the hole shall be refilled and soaked until the drop per increment of time is steady. The time for the water level to drop from a depth of 9 inches to a depth of 6 inches divided by 3 will be the percolation rate in minutes per inch. The maximum percolation rate for new construction is 60 mpi.

6. If the water level cannot be maintained at 12 inches for the minimum time of 15 minutes, then 24 gallons is added to the percolation hole. If the 24 gallons can be added to the percolation hole within the 15 minutes, the percolation rate is 2 mpi. This is with the approval of the Approving Authority.

Required/Suggested Equipment for Percolation Tests		
1.	**Water**	A minimum of 24 gallons is needed per percolation test. Bring sufficient quantities or have an available source on-site.
2.	**Post Hole Digger**	
3.	**Measuring Tape**	(25 foot minimum)
4	**Shovel**	
5.	**Batter Board**	Provides a reference level at the top of the percolation test hole.
6.	**18” Ruler**	Measures water levels during the percolation test.
7.	**Pocket knife**	Is useful in close up examination of the soil.

DEEP OBSERVATION HOLE

The deep observation hole is excavated in order to determine and record the kind of soil on-site and to determine maximum high-groundwater elevations. The information determined from the deep observation hole is critical in assigning a correct soil type and, along with the percolation rate, will determine the appropriate loading rate to be used in designing the sewage disposal system.

Deep observation holes must be excavated on every lot on which a leaching facility is proposed. Holes must be excavated to a depth 4 feet below the bottom of the proposed leaching facility and should be a minimum of ten feet deep. There are instances, however, when the ten-foot depth is not attainable due to the presence of bedrock or other limiting factors.

The deep observation holes should be located in the area of the proposed primary and reserve leaching systems. Site characteristics such as topography, drainage and slope should indicate the most suitable location of the holes.

Soil Logs

Soil logs are the record of the site visit. They should include the data necessary for the design of the sewage disposal system. Essentially, the soil log should show the soil profile with appropriate horizon identified, general location of all test holes, percolation test results, percolation test depths, soil classification, and the presence of ground water and elevation of maximum groundwater.

Whereas design loading rates are based on soil classification as well as percolation rate, it is important to indicate the soil type as determined from the USDA Textural Triangle (Figure 5-1) on the soil log. Having all this information on a well-organized and standardized form will aid greatly in providing accurate information for future reference.

Accuracy is important in preparing the soil logs because, as previously stated, it will be the record of the site visit. One cannot rely on memory to fill in gaps in the soil log. Accurate logs are invaluable in establishing a database of local conditions that in turn will make future site evaluations easier and more productive. In addition, accurate soil logs can provide answers if someone were to have questions at some time in the future.

Putting It All Together

After the site visit is over, the information should be reviewed and checked against any preliminary plans that have been prepared. In this manner, appropriate siting of the sewage disposal system can be confirmed and the design can proceed to completion.

If the procedures outlined in this chapter are followed, site evaluation will provide valuable data on which a subsurface sewage disposal system can be properly sited and designed. While the process will not always be easy or necessarily run smoothly, proper preparation and procedure will go a long way in overcoming the inevitable glitches that plague those who toil in the field.

SUMMARY OF SOIL EVALUATION CRITERIA

- Every proposed disposal area shall be assessed based on the following criteria:
    1. Deep observation hole testing
    2. Soil profile determination
    3. Percolation testing
    4. Landscape position
    5. Hydrogeologic properties
    6. Estimating maximum groundwater elevation

- Soil evaluation may be performed at any time of the year.
- Time of testing should be recorded especially in relation to the existing hydrologic conditions.

DEEP OBSERVATION HOLE

- Purpose is to determine the following:
    - soil profile in the proposed disposal area.
    - depth of overburden above ledge, bedrock or impervious layer(s).
    - observed groundwater elevation at the time of testing.
    - adjusted groundwater elevation.
- At least 2 deep observation holes for every proposed disposal area: 2 in primary area, 2 in reserve area.
- Additional holes may be needed to evaluate soil variability.
- Location of deep observation holes should be determined from obvious and permanent benchmarks and noted on the design plans.
- Secure deep holes to prevent accidents.

- Deep observation hole shall have the following 2 segments:
    - one segment about five feet deep to allow for detailed soil observations;
    - an adjoining, deeper part at least 10 ft deep; or
    - extending at least to a depth of 4 ft below the bottom elevation of the proposed soil disposal area if ten foot holes are impossible because of
        - High water tables
        - shallow bedrock or saprolite.
        - human safety.

SOIL PROFILE

- Soil log shall contain the following information for each soil horizon:
  - depth limits of horizon.
  - soil colors including abundance, size and contrast of redoximorphic features.
  - SCS soil textural class
  - estimated percentage of coarse fragments
  - soil structure
  - soil consistence

- Estimate the maximum high groundwater elevation from:
  - observations of the actual high water table during times of seasonal high water tables;
  - soil morphology and reference wells to correlate water tables during periods when the water table is not at the annual high range;
  - USGS (Frimpter) method to estimate seasonal high water tables;
  - in coastal areas subject to tidal influence, a MassDEP-approved method.

- Determine the presence of 4 feet of pervious naturally-occurring materials throughout the proposed disposal area**.**

LANDSCAPE POSITION

- Identify and record the topography of the proposed disposal area on the evaluation form.

- Record features that may negatively affect the functioning of the system, including:
  - bedrock outcrops and areas with many coarse fragments
  - steep slopes (greater than 3:1) exhibiting signs of unstable soil
  - highly disturbed soil (presence of construction debris, etc.).
  - low-lying coastal areas exhibiting signs of tidal inundation or tidal marsh vegetation.
  - low-lying inland areas exhibiting signs of surface water runoff, ponding or freshwater vegetation.
  - flat low-lying areas adjacent to surface water bodies and streams.

- The boundary of a velocity zone shall be determined by reference to the National Flood Insurance Program Flood Data and Flood Insurance Maps for each community.

HYDROGEOLOGIC PROPERTIES

- The following hydrogeologic properties shall be identified and recorded on the evaluation form:
  - estimated direction of groundwater flow
  - groundwater table elevation observed
  - adjust by USGS water year data and/or soil redoximorphic features
  - actual or estimated depth to bedrock
  - depth of the unsaturated soil zone
  - SCS soil drainage class
  - lateral distance to surface water and/or wetland boundaries
  - location of every public or private water supply:
    - within 400 ft of the proposed system location in the case of public water supply wells;
    - surface water supplies and gravel packed public water supply wells;
    - within 250 ft of the proposed system location in the case of tubular public water supply wells;
    - within 150 ft of the proposed system location in the case of private water supply wells

- Approximate safe yield or design capacity of every public water supply
- Location of proposed disposal area in relation to any Nitrogen Sensitive Areas

ESTIMATING MAXIMUM GROUNDWATER ELEVATION

- WET SEASON
  - when is the wet season truly wet?
  - allows testing only during a limited time period
  - how representative is the observed water level?

- USGS Procedure
  - allows prediction throughout the year
  - works well in large, unconfined sandy strata such as outwash and deltas
  - prediction general in scale, does not precisely estimate onsite conditions
  - limited applicability in confined deposits such as clays and tills
  - requires some technical skills
  - need reference well close by

- WET SEASON BASED ON LOCAL WELL NETWORK
  - better estimate as to how wet is wet
  - requires long-term time and financial commitment
  - does not estimate actual on-site conditions

- SOIL MORPHOLOGY
  - does not estimate absolute maximum high groundwater elevation, but a more average value
  - can be used throughout the year
  - requires interpretive skills
  - morphology reflects long-term hydrology

SOIL LOG EXAMPLE

Commonwealth of Massachusetts
City/Town of Our Town
Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review (*minimum of two holes required at every proposed primary and reserve disposal area)*

Deep Observation Hole Number: 1 | 8-19-2016 (Date) | 12:30 (Time) | p. cloudy (Weather)

1. Location
   Description of Location: Building Lot

2. Land Use: building lot (e.g., woodland, agricultural field, vacant lot, etc.)
   many — Surface Stones (e.g., cobbles, stones, boulders, etc.)
   2-3% — Slope (%)
   none — Vegetation
   ground moraine — Landform
   ______ Position on Landscape (SU, SH, BS, FS, TS)

3. Distances from: Open Water Body NA feet; Drainage Way NA feet; Wetlands NA feet
   Property Line >25' feet; Drinking Water Well NA feet; Other ______ feet

4. Parent Material: glacial till   Unsuitable Materials Present: ☐ Yes ☒ No

   If Yes: ☐ Disturbed Soil ☐ Fill Material ☐ Impervious Layer(s) ☐ Weathered/Fractured Rock ☐ Bedrock

5. Groundwater Observed: ☐ Yes ☒ No   If yes: ______ Depth Weeping from Pit ______ Depth Standing Water in Hole

Deep Observation Hole Number: 1

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
0-8	A	10YR 3/3			0	sl			granular	friable	
8-20	Bw	10YR 5/8			0	sl			massive	friable	
20-88+	C	10 YR 4/4	48"	7.5YR 5/8*	2%	gsl		20%	massive	friable	

Additional Notes:

* Weathering rocks indicates fluctuating water level, roots to 60”

PERCOLATION TEST PROCEDURE

- Conduct the test in the most limiting soil layer.

- Test may be conducted at any time of the year except when soil is frozen.

- A minimum of 1 perc test per disposal area:

    - One perc test located in or very close to the proposed primary leaching area
    - One perc test located in or very close to the proposed reserve area
    - More testing may be required depending on soil variability and size of disposal system proposed.

- Test hole specifications:

    - Diameter: 12”
    - Depth: 18”.

- Establish fixed reference point from which to make all measurements.

- Scratch the bottom and sides of the test hole to remove smeared soil surfaces.

- To prevent scouring of the hole bottom, while pouring water in the test hole either put 2 inches of a coarse sand or use a board or other impervious object at the bottom of the hole.

- In very sandy soils a coarse wire mesh or perforated liner may be used to prevent sloughing of the soil and to maintain proper hole dimensions, with the Board of Health’s permission.

- Carefully fill the hole with water to a minimum of 12” from the bottom of the hole.

- Add water to the hole as needed to maintain the level to a minimum of 12” above the bottom of the hole for a period of at least 15 minutes.

- After this saturation period, allow water level to drop to the depth of 9”, and then determine the length of time required to drop the level from a depth of 9” to a depth of 6”.

- Calculate the percolation rate by dividing the number of minutes for the water level to drop from 9" to 6” by 3.

- In coarse sands and similar rapidly permeable materials, when at least 24 gallons of water has been added to the hole within 15 minutes and it is impossible to obtain a liquid depth of nine inches, a percolation rate of 2 minutes/inch is assumed.

ESTIMATING PROBABLE HIGH GROUNDWATER ELEVATIONS

Reference:
Frimpter, M.H. 1981. Probable high ground-water levels in Massachusetts.
http://pubs.usgs.gov/of/1980/1205/report.pdf

SUMMARY

The U.S. Geological Survey (USGS), in collaboration with various Massachusetts state agencies, has been monitoring monthly water table levels in observation wells throughout the state since the 1930s. These long-term records allow prediction of seasonally high water tables in certain soil parent materials. The USGS method (also referred to as the “Frimpter Method”) allows estimation of the seasonal high groundwater elevation at a proposed groundwater discharge site based on current groundwater levels at the test site and the ratio of the present water level to the historic water level range in the nearest network observation well located in the same geologic strata as the proposed discharge site.

> The method works well in unconsolidated sands and gravels typically associated with glacial outwash and deltas. Due to the local character of precipitation patterns, the selected reference observation well and the test site need to be part of the same hydrogeologic environment. Actual water levels will not exceed estimates based on this method at a rate greater than 1 in every 10 years. The method works best in sandy strata of southeastern Massachusetts, including the southern portion of Cape Cod and the Islands; however, it can be used in unconsolidated formations throughout the Commonwealth.

INTRODUCTION

For soil evaluation purposes this elevation is commonly estimated using soil morphology, principally the presence of redoximorphic features. While this method works well under most natural conditions, it may lead to erroneous conclusions in certain situations, particularly when the soil evaluator is inexperienced. Sandy soils, soils (red, black, gray) where the color masks the presence of redoximorphic features, or soils with E and Bhs horizons (Spodosols), are examples of situations where soil morphological features may be problematic. This tends to be only a small portion of all soils in Massachusetts. However, the distinct presence of redoximorphic features in the test pit is the best sign of probable high groundwater elevations. Figure 10-1 exhibits redoximorphic features in soil samples and a test pit.

Another approach to assess the high groundwater elevation may be to observe the soil during the so-called "wet season”, typically February through April. The problem with this approach is that high water table levels vary seasonally and annually. These effects are illustrated in Figure 10-1, where over a 3-year period the water table fluctuated between 21.8 feet below the soil surface in April 1970 and 28 feet in November 1971. Typically these fluctuations are dependent on the type of parent material. The maximum range of water levels (9 out of 10 years) between spring and fall is estimated to be 16 feet in tills, 9.2 feet in sands and gravels on terraces, and 4 feet in sands and gravels in valley bottoms (Frimpter, 1981).

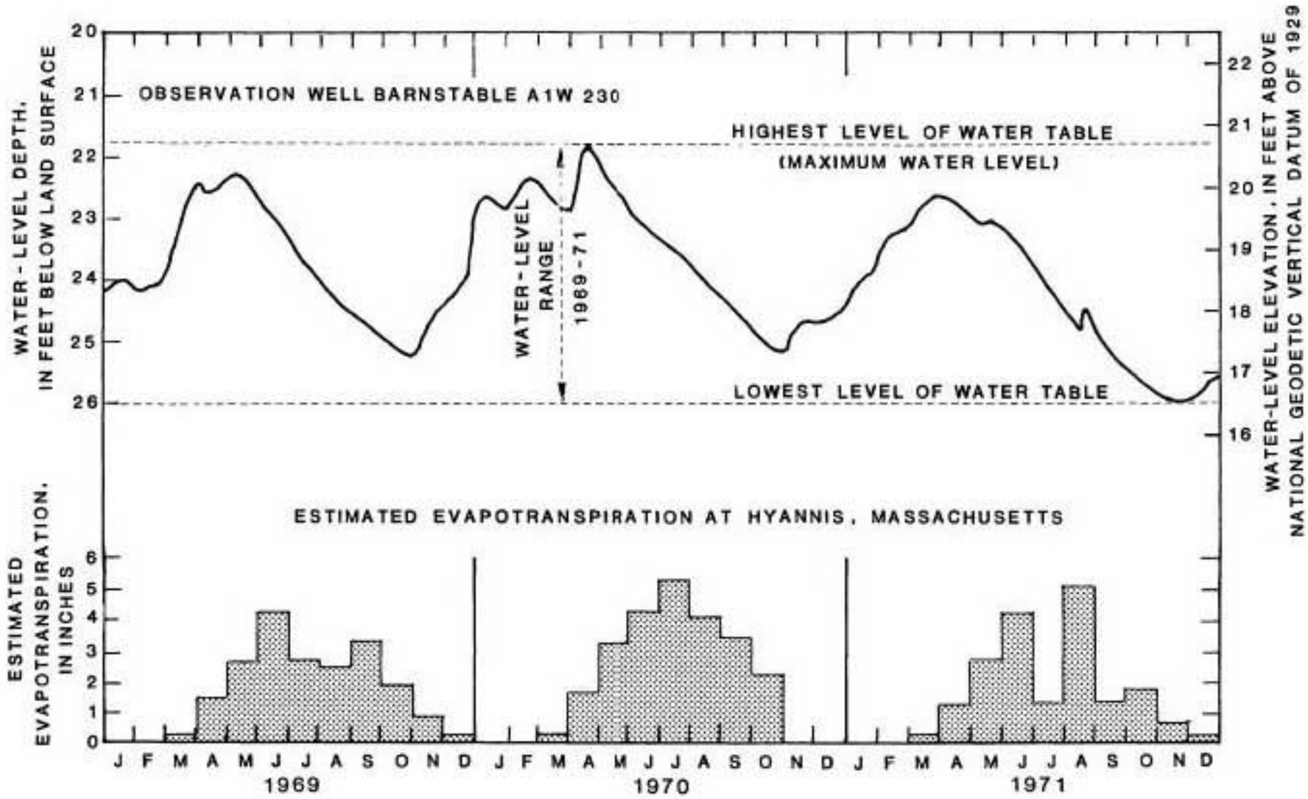


Figure 10-1: Barnstable Well A1W 230 seasonal water-level fluctuations, 1969-1971

ESTIMATING HIGH GROUNDWATER ELEVATION – THE WET SEASON APPROACH

Figure 10-1 shows the limitations of the wet season approach to determine seasonal high water tables. The highest groundwater elevation during this 3-year period was at 21.8 feet below the soil surface during a short time in April 1970. In 1969 the highest groundwater elevation was 22.3 feet, and in 1971 the maximum elevation was at 22.6 feet. Using the wet season approach each year would have resulted in a difference of about 10 inches during the 1969-1971 period. If we had considered many more years of observations, this difference would have been even greater. Furthermore, neither the duration nor the groundwater elevation is constant throughout the wet season (Table 10-1). In 1969, the period with the highest average water table elevation ran from the end of March to the middle of May. An observation in early March would have indicated a groundwater elevation of about 24 feet, almost 2 feet below the level at the end of that month. In 1970 the period with the highest average groundwater elevation started in early January and lasted to about the middle of May. Observations during any other time would have resulted in a significant underestimation of the high groundwater elevation. The period with the highest average water table elevations in 1971 went from the end of February to the end of May. Clearly, there is no distinct period of time of fixed duration in which groundwater elevations remain at a constant high level. For the Barnstable 230 USGS observation well the high groundwater elevation estimates varied by as much as 0.6 feet (7 inches) during this 3-year period (Table 10-1). Therefore, by using just the wet season approach, you are limited in estimating when that season occurs each year, because it may occur at different times from year to year, with various ranges of water level fluctuations.

	Season of Maximum Average groundwater Elevation	Length of wet Season (months)	Average Groundwater Elevation Below Surface (feet)
1969	March (end)- May (middle)	1.5	22.4
1970	January (begin) – May (middle)	4.5	22.6
1971	February (end) – May (end)	3	23.0

Table 10.1. Wet season duration and average groundwater elevation for the Barnstable 230 observation well during the years 1969 through 1971.

THE USGS OBSERVATION WELL NETWORK

The duration of the wettest season and the level of the groundwater elevation depend on climatic conditions that are often not predictable in the short term. These include the amount of precipitation during and prior to the time of observation. It also depends on air temperatures that in turn affect plant growth and, consequently, the rate of evapotranspiration. Average precipitation in Massachusetts tends to be constant throughout the year, although patterns may vary from year to year. Potential evapotranspiration rates increase with temperature and development of vegetation. It generally peaks in July and August and is about zero during the winter months (Figure 10-1). During the growing season when evapotranspiration rates are high, the soil dries out and the water table drops, reaching its lowest elevations in September and October, except during periods of heavy precipitation such as during hurricanes and other catastrophic storm events. The decrease in evapotranspiration and fairly constant precipitation rate causes water to be stored in the soil during late fall and early winter. Once the soil's water storage capacity is exceeded, water starts draining and replenishing the groundwater and water tables rise. Most groundwater recharge occurs during late winter and early spring from precipitation and melting snow and ice. Annual groundwater levels generally reach their maximum elevation during this time period (Frimpter, 1981).

Starting in the 1930s, the USGS, in collaboration with the Massachusetts Department of Public Works, established a network of observation wells throughout Massachusetts. Today there are close to 200 observation wells monitored on a monthly basis. The wells were installed in representative parent materials and landforms throughout the state. Water table elevations are measured at the end of every month. The information is entered in a computer database that is available at: http://groundwaterwatch.usgs.gov/statemap.asp?sc=25&sa=MA

The same website contains maps comparing the monthly readings with the historical record. This allows one to instantly assess whether an area has normal groundwater levels. Normal is defined as being within 25 percentiles of the median value. Water levels above the normal range fall in the upper 25% of all observations for that well during that month. Conversely, groundwater levels in the lowest 25% of all observations are considered below normal.

ESTIMATING HIGH GROUNDWATER ELEVATION - MODIFIED WET SEASON APPROACH

As discussed earlier, estimating high groundwater elevations based on actual water table observations during the wet season may result in erroneous results, because of annual and seasonal hydrologic cycles. The use of the USGS observation network data may improve the accuracy of this procedure. For example, any test pit groundwater observations on Cape Cod made during late February 2000 were highly suspect because the USGS *Current Conditions* map for that month shows that water tables during that time period were in the lowest 25% of all observations recorded for that month in that area. The Barnstable well was put in operation in 1957, thus the record spans a period of more than 40 years. If on the other hand the observations were conducted on the North Shore and the water table was observed at a depth of 7 feet, we could conclude that this depth reflected close to the highest water table elevation because the historical record indicates that water table levels for that month were in the upper 25% of all observations ever taken in February in that region. Use of the USGS observation network thus allows comparisons of the observed water table level at a location with the historical record of observation wells in that area. This approach ensures that observations during the wet season indeed reflect the wettest conditions for that area.

Some Boards of Health have used correction factors based on the USGS observation network to correct for testing conditions when water tables are not at maximum levels. This approach is based on the principle that if the water table in an observation well is below normal, this lower level is reflected at other sites within the town as well. Although that is true qualitatively (i.e. water table elevations probably will be lower in other parts of the town), it does not mean that the levels are numerically the same at all locations. Just because the level in an observation well is 1 foot below the mean for that month, not all sites within that town have water tables that are 1 foot below the mean for that location. Actual groundwater levels depend on parent material, local weather events, and hydrogeologic conditions. Only when a municipality has an extensive network of observation wells in a variety of geologic strata throughout the town, can differences in water table levels be properly assessed. Few towns are willing to invest time and resources in such an observation network, nor do they have the technical expertise available to derive a realistic correction factor. A better approach to predict water table elevations at a certain location is to use the USGS estimation procedure that is explained in the following sections.

In urban areas the hydrology may have been altered by sewering, installation of storm drains, paving, and drainage alterations, and the presence and depth of redoximorphic features may no longer reflect the current hydrology. Use of the USGS observation well network in combination with on-site water table measurements allows for a reasonably accurate determination of the new seasonal high groundwater elevation. If it is suspected that the redoximorphic features no longer represent the current hydrology, excavate a test hole during the time period when observation wells indicate maximum high groundwater levels for that area. The actual water level during that time period should be indicative of the new seasonal high water table. Installation of a well on-site may facilitate the determination of the period with maximum high water tables. When using this estimation procedure, it is crucial that the water table in the observation well indeed reflects groundwater levels that are within the upper 10% of historic observations for that month. If the groundwater does not indicate maximum levels during field testing, the USGS method may provide a better estimate of the seasonal high groundwater elevation.

ESTIMATING HIGH GROUNDWATER ELEVATION – USGS METHOD

Long-term monthly measurements of water levels in observation wells located throughout Massachusetts provide a record of maximum, mean, and lowest high water table levels on a monthly basis. These values differ by parent material and location, resulting from differences in physical soil properties, bedrock configuration, and climatic conditions throughout the state. The longer the period of measurement, the more refined the data set becomes. The USGS method is based on the principle that water tables in wells fluctuate in a similar fashion when installed in hydrologically connected aquifers. In unconfined sands and gravels these fluctuations may even be numerically identical. The numerical difference between water table levels in various observation wells may show a high degree of correlation, although numerically the fluctuations may not necessarily be the same. The correlation is strongest when observation wells are grouped by parent material.

Each year the USGS publishes summary statistics for each well in the network on its website at http://waterdata.usgs.gov/ma/nwis/current/?type=gw&group_key=county_cd. The information for each observation well includes: year that monitoring started, elevation, maximum depth of the well, parent material, landform, maximum water level on record (OW_{max}), lowest water level ever recorded, and the recorded upper limit of the **annual** range for that well (OW_r). Note that the value for OW_r is generally less than the difference between OW_{max} and the lowest groundwater elevation value on record because the most extreme values are deleted from the tabulation.

The high groundwater elevation at a site can be estimated by correlation with the potential rise in a network observation well, if the climate and hydrogeologic conditions at the site and the well are similar. If the site has till parent material, the observation well selected for the estimation also should have till, occur on a similar landform, and be as close to the site as possible. Similarly, in sandy soils the observation well used for the calculation should be in sandy and gravelly outwash or comparable deposits, in the same landscape position (i.e. either on terraces or in valleys), and as close by as possible. The high groundwater elevation can be estimated using the following equation (Frimpter, 1981):

$$S_h = S_c - [S_r \times (OW_c - Ow_{max})/OW_r]$$

Where:

S_h	= estimated depth to the high groundwater elevation at the proposed groundwater discharge site
S_c	= measured depth to the current groundwater elevation at the site
S_r	= expected range in water levels at the site. This value is based on the combined records of all observation wells for that parent material and landform.
OW_r	= historical upper limit of the annual range for the selected observation well
OW_c	= measured depth to the present groundwater elevation in the selected observation well
Ow_{max}	= maximum groundwater elevation on record for the selected observation well

The value for S_c is determined by measuring the actual groundwater elevation at the site for the proposed leaching facility. The measurement should be taken towards the end of the month, because the USGS observation wells are always read near the end of each month. Landform and type of parent material are typically recorded during the soil evaluation. If such an assessment has not been made as yet, the landform and associated parent material need to be determined at the location of the proposed leaching facility when S_c is measured.

The value for S_r is selected from probability graphs (see Figures 10-2 and 10-4). These figures depict the maximum range in groundwater elevations in a particular parent material given a certain probability. Frimpter (1981) developed charts for sands and gravels (typically outwash, kames, or deltas) either on terraces (Figure 10-2) or on valley floors (Figure 10-3) and for glacial till (Figure 10-4). These charts show the maximum range that one can expect in a parent material given a certain probability level. For example, Figure 10-2 indicates that in a coarse textured kame terrace the groundwater level range between early spring and late summer will exceed 10 feet 5% of the time (i.e. one out of every 20 years). The maximum range of 9.4 feet will be exceeded 10% of the time (i.e. one out of every 10 years). These values are obtained by selecting an appropriate probability level (for example 5%) and drawing a vertical line at the 5% level (see Figure 10-2). At the point where the vertical and the curve intersect, draw a horizontal line towards the left. The intersect with the Y-axis determines the level that may be exceeded at that probability level.

OW_r and OW_{max} are parameters based on long term measurements of groundwater levels in the USGS observation well network. At the end of each month the groundwater level in every well is measured and the data are entered into a database accessible through the USGS website, http://waterdata.usgs.gov/ma/nwis/current/?type=gw&group_key=county_cd. The data are tabulated and compared to previously collected groundwater levels. OW_{max} represents the highest groundwater elevation that reasonably can be expected in that particular reference well. OW_r represents the maximum range in values that can be expected for that observation well. As noted earlier, the value for OW_r is generally less than the difference between OW_{max} and the lowest groundwater elevation value on record because the most extreme values are deleted from the tabulation. Values for OW_{max} and OW_r can be obtained from the USGS website. If the observation well was installed many years ago, the OW_{max} and OW_r values will not change much from one year to another. If the well installation was more recent it is imperative that the values of these parameters are obtained from the most current data on the USGS website.

The value of OW_c reflects the groundwater elevation in the observation well during the same month that the groundwater level at the proposed groundwater discharge site is determined. Select the appropriate month from the USGS website. Values for OW_c are the monthly well readings that are available in the monthly data table.

SANDS AND GRAVELS ON TERRACES

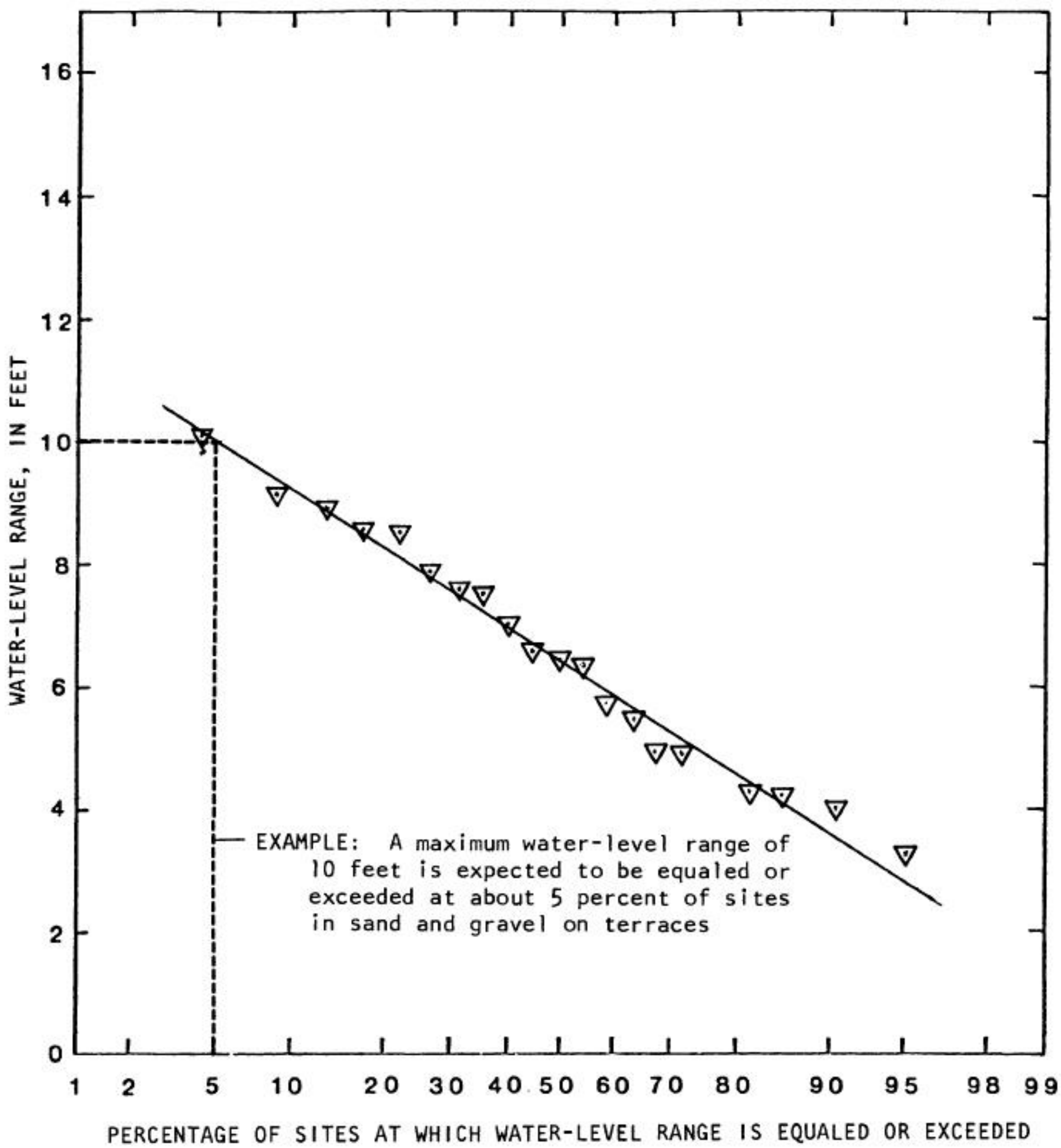


Figure 10-2. Probability of water-level range in sands and gravels on terraces (source: Frimpter, 1981)

SANDS AND GRAVELS IN VALLEY FLATS

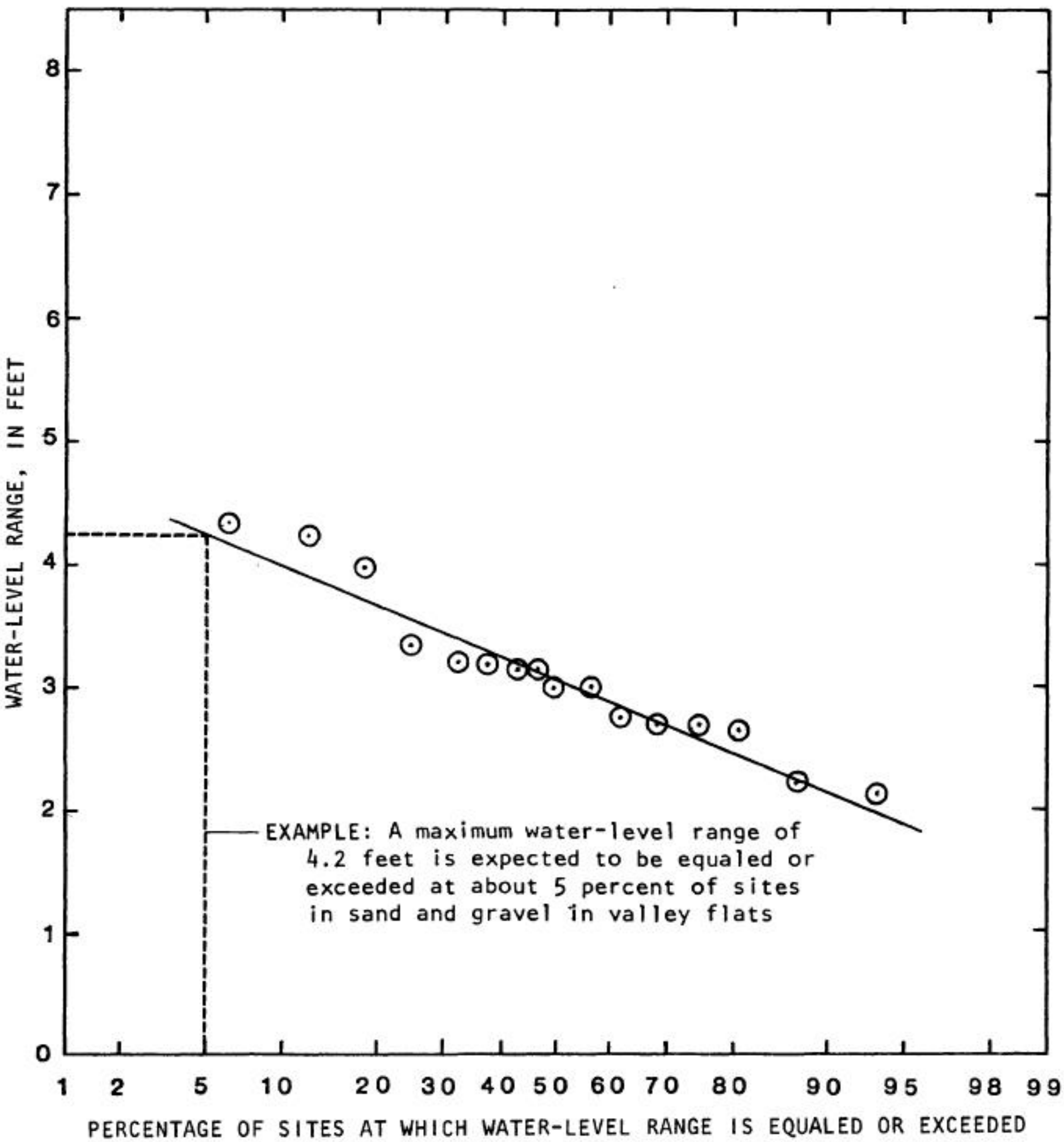


Figure 10-4. Probability of water-level range in sands and gravels in valley flats. (source: Frimpter, 1981)

TILL

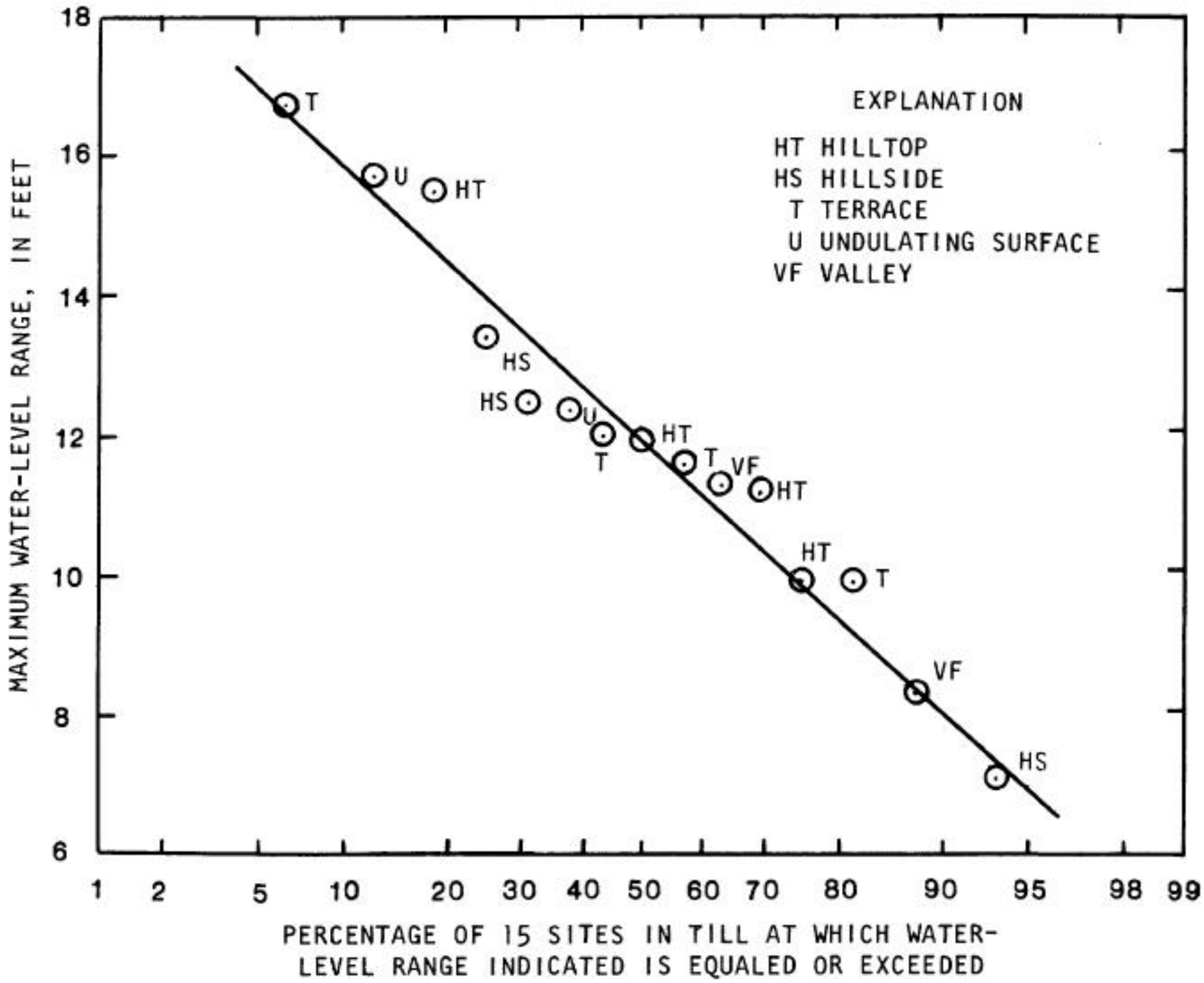


Figure 10-5. Probability of water-level range in till (source: Frimpter, 1981)

Sample Calculation to Estimate High Groundwater Elevation Using the USGS Method

The following provides an example demonstrating how one may calculate the high groundwater elevation at a site in Lakeville, located in southeastern Massachusetts. An earlier soil evaluation showed that the site was located on stratified sandy deposits on a kame terrace. The groundwater level at the proposed groundwater discharge site is 8.0 feet below the soil surface. The groundwater level was measured on February 27, 2000.

Using the equation on page 6 we can calculate the high groundwater elevation at the proposed leaching facility. Following is an explanation of the origin of the various values used in the calculation. The value for Sc is determined at the proposed leaching facility site by measuring the groundwater elevation. As stated in the previous paragraph this level was determined to be 8.0 feet.

The value for S_r is selected from probability graphs (see Figures 10-2 and 10-4). The parent material for the proposed site is sandy sediments located on a kame terrace. Figure 10-2 is for sand and gravel deposits on terraces and should be used to estimate S_r. Let's assume that we want to predict the high groundwater elevation based on a probability that this value will not be exceeded more than once in 20 years (5% probability). Draw a vertical line at the 5% probability level and determine the intersect with the probability curve. In Figure 10-3, this is illustrated by the dashed line. At the intersect draw a line to the left parallel with the X-axis. The intersect with the Y-axis gives the value for S_r for the 5% probability level. In this example S_r equals 10.0 feet.

The next step to calculate the estimated probable high groundwater elevation is to select an appropriate USGS observation well. The #14 well in Lakeville is nearby and is located in the same aquifer as the proposed groundwater discharge site and therefore can be used as a reference well. For the purposes of this exercise we will assume that the values for OW_{max} and OW_r are 9.28 and 10.45 feet, respectively. Also, OWc will have a value of 16.1 feet in February. (Value for OWc is obtained from the USGS website for the same month that Sc was measured, http://waterdata.usgs.gov/ma/nwis/current/?type=gw&group_key=county_cd).

All variables now have been determined and can be substituted in equation (1) as **follows:**

$$\mathbf{Sh = S_c - [S_r \times (OW_c - OW_{max})/OW_r]}$$

$$\mathbf{Sh = 8.0 - [10.0 \times (16.1 - 9.28)/10.45] = 1.5\ feet}$$

Note: always subtract the numbers in parentheses first before multiplying and dividing.

The predicted high groundwater level at the proposed site is 1.5 feet below the soil surface. This indicates that there is not enough separation between the high groundwater level and the bottom of the proposed leaching facility. Use of clean fill (see Regulation 310 CMR 15.00 for fill specifications) can increase this distance to the proper level. If the underlying soil has a percolation rate faster than 2 minutes per inch, the separation distance should be 5 feet. If the perc rate is slower than 2 minutes per inch, the separation between the high groundwater elevation and the bottom of the leaching facility should be a minimum of 4 feet. High water tables do not automatically exclude a site for on-site sewage treatment and disposal systems. They do require a special design approach that generally increases installation costs.

Keep in mind that the distinct presence of redoximorphic features in the test pit is the best sign of high groundwater elevations. If these features are vague or non-existent, then the Frimpter Method is the next best approach in determining probable high groundwater at the proposed groundwater discharge site. The State Environmental Code, Title 5, in particular 310 CMR 15.103(3), outlines the methodologies allowed in determining probable high groundwater.

APPENDIX A

GLOSSARY/DEFINITIONS/REFERENCES

APPENDIX A-1: GLOSSARY OF SOIL SCIENCE TERMS FOR SOIL EVALUATORS

Ablation till. Loose, permeable till deposited during the final down-wasting of glacial ice. Lenses of crudely sorted sand and gravel are common.

Aggregate. Many fine particles held in a single mass or cluster. Natural soil aggregates, such as granules, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.

Alluvium. Material, such as sand, silt, or clay, deposited on land by streams.

Basal till. Compact glacial till deposited beneath the ice (Lodgement Till is preferred).

Bedrock. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Boulders. Rock fragments larger than 2 feet (60 centimeters) in diameter.

Clay particles. As a soil separate, the mineral soil particles less than 0.002 millimeters in diameter.

Clay soil. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

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.

Cobblestone (or cobble). A rounded or partly rounded fragment of rock 3 to 10 inches (7.5 to 25 centimeters) in diameter.

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

Consistence. The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms **commonly used to describe consistence 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.
>
> **Firm**: When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.
>
> **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.
>
> **Sticky**: When wet, adheres to other material and tends to stretch somewhat and pull apart rather than to pull free from other material.
>
> **Hard**: When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.
>
> **Soft**: When dry, breaks into powder or individual grains under very slight pressure.
>
> **Cemented**: Hard; little affected by moistening.

Drumlin. A low, smooth, elongated oval hill, mound, or ridge of compact glacial till. The longer axis is parallel to the path of the glacier and commonly has a blunt nose pointing in the direction from which the ice approached.

Eolian soil material. Soil material accumulated through wind action; commonly refers to sandy material in dunes or to loess in blankets on the surface.

Glacial outwash. Gravel, sand, and silt, commonly stratified, deposited by glacial meltwater.

Glacial till. Unsorted, nonstratified glacial deposits consisting of clay, silt, sand, and boulders transported and deposited by glacial ice.

Glacial fluvial deposits. Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and occur as kames, eskers, deltas, and outwash plains.

Glacial lacustrine deposits. Material ranging from fine clay to sand derived from glaciers and deposited in glacial lakes mainly by glacial meltwater. Many deposits are interbedded or laminated.

Hardpan. A hardened or cemented soil horizon, or layer. The soil material is sandy, loamy, or clayey and is cemented by iron oxide, silica, calcium carbonate, or other substance.

Impervious soil. A soil through which water, air, or roots penetrate slowly or not at all. No soil is absolutely impervious to air and water all the time.

Kame. An irregular, short ridge or hill of stratified glacial drift.

Loess. Fine grained material, dominantly of silt-sized particles, deposited by wind.

Mineral soil. Soil that is mainly mineral material and low in organic material. Its bulk density is more than that of organic soil.

Moraine (geology). An accumulation of earth, stones, and other debris deposited by a glacier. Some types are terminal, lateral, medial, and ground.

Munsell notation. A designation of color by degrees of three simple variables; hue, value, and chroma. For example, a notation of 10YR 6/4 has a hue of 10YR (yellow-red), value of 6, and chroma of 4.

Organic matter. Plant and animal residue in the soil in various stages of decomposition.

Outwash, glacial. Stratified sand and gravel produced by glaciers and carried, sorted, and deposited by glacial meltwater.

Outwash plain. A landform of mainly sandy or coarse textured material of glaciofluvial origin. An outwash plain is commonly smooth; where pitted, it is generally low in relief.

Parent material. The unconsolidated organic and mineral material in which soil forms.

Ped. An individual natural soil aggregate, such as a granule, a prism, or a block.

Percolation. The downward movement of water through the soil.

Permeability. The quality of the soil that enables water to move downward through the profile. Permeability is measured as the number of inches per hour that water moves downward through the saturated soil.

Ponding. Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by percolation or evapotranspiration.

Redoximorphic features. Irregular spots of different colors that vary in number and size. Redox features indicates poor aeration and impeded drainage, and areas of fluctuating water levels.

Sand particles. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz.

Sand as a soil textural class. A soil that is 85 percent or more sand and not more than 10 percent clay.

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

Silt particles. Individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter).

Silt as a soil textural class. Soil that is 80 percent or more silt and less than 12 percent clay.

Soil. A natural, three-dimensional body at the earth's surface which supports life (plant, animal or microbial). Soil has properties resulting from the integrated effect of climate and living matter acting on mineral parent material, as conditioned by relief over periods of time.

Soil horizon. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. In the identification of soil horizons, an uppercase letter represents the major horizons. Numbers or lowercase letters that follow represent subdivisions of the major horizons. The major horizons are as follows:

> **A horizon**. The mineral horizon at or near the surface in which an accumulation of humified organic matter is mixed with the mineral material. Also, any plowed or disturbed surface layer.
>
> **E horizon**. The mineral horizon in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these.
>
> **B horizon.** The mineral horizon below an O, A, or E horizon. The B horizon is in part a layer of transition from the overlying horizon to the underlying C horizon. The B horizon also has distinctive characteristics, such as (1) accumulation of clay, sesquioxides, humus, or a combination of these; (2) granular, prismatic, or blocky structure; (3) redder or browner colors than those in the A horizon; or (4) a combination of these.
>
> **C horizon.** The mineral horizon or layer, excluding indurated bedrock, that is little affected by soil-forming processes and does not have the properties typical of the overlying horizon. The material of a C horizon may be either like or unlike that in which the solum formed. If the material is known to differ from that in the solum, an Arabic numeral, commonly a 2, precedes the letter C.
>
> **R layer.** Hard, consolidated bedrock beneath the soil. The bedrock commonly underlies a C horizon but can be directly below an A or a B horizon.

Soil Morphology. The physical makeup of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.

Soil Profile. A vertical section of the soil extending through all its horizons and into the parent material.

Soil structure. The arrangement of primary soil particles into compound particles or aggregates. 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).

Stones. Rock fragments 10 to 24 inches (25 to 60 centimeters) in diameter.

Subsoil. Technically, the B horizon; roughly, the part of the soil below the A or Ap horizon.

Subsurface layer. Any surface soil horizon (A, E, AB, or EB) below the surface layer.

Surface layer. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, ranging in depth from about 4 to 10 inches (10 to 25 centimeters). Frequently designated as the ""plow layer,'' or the ""Ap horizon.''

Surface soil. The A, E, AB, and EB horizons. It includes all subdivisions of these horizons.

Terminal moraine. A belt of thick glacial drift that generally marks the termination of important glacial advances.

Terrace (geologic). An old alluvial plain, ordinarily flat or undulating, bordering a river, a lake, or the sea.

Soil Texture. The relative proportions of sand, silt, and clay particles in a mass of 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.''

Till plain. An extensive flat to undulating area underlain by glacial till.

Toe slope. The outermost inclined surface at the base of a hill; part of a foot slope.

Topsoil. The upper part of the soil (A or Ap Horizon), which is the most favorable material for plant growth. It is ordinarily rich in organic matter.

Variegation. Refers to patterns of contrasting colors assumed to be inherited from the parent material rather than to be the result of poor drainage.

Varve. A sedimentary layer of a lamina or sequence of laminae deposited in a body of still water within a year. Specifically, a thin pair of graded glaciolacustrine layers seasonally deposited, usually by meltwater streams, in a glacial lake or other body of still water in front of a glacier.

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.

APPENDIX A-2: TITLE 5 DEFINITIONS

Bedrock - Solid rock exposed at the surface or overlain by unconsolidated gravel, sand, silt and/or clay. Bedrock includes weathered or saprolitic components thereof. Bedrock types are defined and most of their areal extent are described in the "Bedrock Geologic Map of Massachusetts" published by the Massachusetts Department of Public Works (1983).

Deep Observation Hole - An open pit dug to permit examination of the soils and to obtain data relative to the mean annual high groundwater elevation.

Impervious Material - Soils with a percolation rate greater than 60 minutes per inch. (See, also, the definition of unsuitable material.)

Naturally Occurring Pervious Material - Naturally occurring soil exhibiting a percolation rate of 60 minutes or less per inch which was deposited on a site by natural causes and not by human action.

Pervious Soil **-** Soil with a percolation rate of 60 minutes per inch or less found in the B and C horizons.

Saturated Zone - Any portion of the earth below the land surface where available openings (pore, fissure, joint or solution cavity) are filled with water.

Soil Evaluator - A person approved by the Department pursuant to 310 CMR 15.017 as capable of evaluating the suitability of a specific site for the use of an on-site subsurface sewage disposal system in compliance with 310 CMR 15.000.

Soil Texture - The relative proportions of sand, silt and clay in a given soil medium as defined by the USDA/NRCS.

Unsuitable Material – All impervious material, all organic sediments, and all material found in the following horizons: O (organic), A (topsoil), and E (mineral). All bedrock, including saprolite or weathered bedrock, schist, and ledge. (see, also, the definition of impervious material).

APPENDIX A-3: SELECTED ON-LINE SOIL REFERENCES

Soil Survey Manual – USDA –NRCS- Soils – Technical References – Soil Survey Manual
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054262

Web Soil Survey: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Official Soil Series Descriptions – USDA –NRCS- Soils – Helping People Understand Soils
https://soilseries.sc.egov.usda.gov/osdname.asp

NESOIL.COM – Providing Soil Information for New England – Massachusetts Soil Survey
http://nesoil.com/massachusetts_soil_survey.htm

APPENDIX B

SAMPLE FORM 11

Commonwealth of Massachusetts
City/Town of Everytown

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

A. Facility Information

John Smith
Owner Name

5 Main Street
Street Address

Map 1, lot 1
Map/Lot #

Everytown
City

MA
State

010XX
Zip Code

B. Site Information

1. (Check one) ☒ New Construction ☐ Upgrade ☐ Repair

2. Soil Survey Available? ☐ Yes ☐ No If yes: websoilsurvey (Source) 305B (Soil Map Unit)

   Paxton Fine Sandy Loam
   Soil Name

   ahallow to bedrock, poorly drained
   Soil Limitations

   Glacial Till (basal/lodgement)
   Soil Parent material

   Drumlin
   Landform

3. Surficial Geological Report Available? ☒ Yes ☐ No If yes: 1975 (Year Published/Source) Qt (Map Unit)

   Light Grey to olive grey poorly sorted mixture of sand, gravel, boulders and minor silt
   Description of Geologic Map Unit:

4. Flood Rate Insurance Map Within a regulatory floodway? ☐ Yes ☒ No

5. Within a velocity zone? ☐ Yes ☒ No

6. Within a Mapped Wetland Area? ☐ Yes ☒ No If yes, MassGIS Wetland Data Layer: ____________ Wetland Type

7. Current Water Resource Conditions (USGS): 3/21/2018 (Month/Day/ Year) Range: ☐ Above Normal ☒ Normal ☐ Below Normal

8. Other references reviewed: SearchWell

Commonwealth of Massachusetts
City/Town of Everytown

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review (*minimum of two holes required at every proposed primary and reserve disposal area)*

Deep Observation Hole Number: #1 (Hole #) | 3/21/2018 (Date) | 10:00 (Time) | overcast (Weather) | XXXX (Latitude) | XXXX (Longitude:)

1. Land Use: agricultural field (e.g., woodland, agricultural field, vacant lot, etc.) | corn stubble (Vegetation) | no, but stonewalls around the field (Surface Stones (e.g., cobbles, stones, boulders,) | 3-8 (Slope (%))

   Description of Location: Farm field approximately 500 feet north of grain shed

2. Soil Parent Material: glacial till | drumlin (Landform) | SU (Position on Landscape (SU, SH, BS, FS, TS))

3. Distances from: Open Water Body >200 feet | Drainage Way > 200 feet | Wetlands NA feet
   Property Line >100 feet | Drinking Water Well NA feet | Other ______ feet

4. Unsuitable Materials Present: ☐ Yes ☒ No If Yes: ☐ Disturbed Soil ☐ Fill Material ☐ Weathered/Fractured Rock ☐ Bedrock

5. Groundwater Observed: ☐ Yes ☒ No If yes: ______ Depth Weeping from Pit ______ Depth Standing Water in Hole

Soil Log

Depth (in)	Soil Horizon /Layer	Soil Texture (USDA	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
				Depth	Color	Percent	Gravel	Cobbles & Stones			
0-10	Ap	ls	10YR 3/3						granular	friable	
10-39	Bw	fsl	10YR 5/6				<10		blocky	friable	roots to 36"
39-51	Cd1	gsl	2.5Y 4/4	39"	7.5YR 5/8	3%	15-20	10	massive	firm	
51-106+	Cd2	sl	5Y 4/4	50"	2.5Y 6/2	5%	10	10	massive	very firm	

Additional Notes:

Commonwealth of Massachusetts
City/Town of Everytown

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review *(minimum of two holes required at every proposed primary and reserve disposal area)*

Deep Observation Hole Number: #2 (Hole #) 3/21/2018 (Date) 11:00 (Time) overcast (Weather) XXXX (Latitude) XXXX (Longitude:)

1. Land Use: agricultural field (e.g., woodland, agricultural field, vacant lot, etc.) corn stubble (Vegetation) no, but stone walls (Surface Stones (e.g., cobbles, stones, boulders, etc.)) 3-8 (Slope (%))

Description of Location: corn field , 500 feet north of grain shed, 20' from pit #1

2. Soil Parent Material: glacial till drumlin (Landform) SU (Position on Landscape (SU, SH, BS, FS, TS))

3. Distances from: Open Water Body >220 feet Drainage Way >220 feet Wetlands NA feet
Property Line >120 feet Drinking Water Well NA feet Other ______ feet

4. Unsuitable Materials Present: ☒ Yes ☐ No If Yes: ☐ Disturbed Soil ☐ Fill Material ☒ Weathered/Fractured Rock ☐ Bedrock

5. Groundwater Observed: ☒ Yes ☐ No If yes: 26" Depth Weeping from Pit 5" Depth Standing Water in Hole

Soil Log

Depth (in)	Soil Horizon /Layer	Soil Texture (USDA)	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
				Depth	Color	Percent	Gravel	Cobbles & Stones			
0-10	Ap	ls	10YR 3/3						granular	friable	
10-24	Bw	sl	10YR 5/6				<10	<2	massive	friable	
24-85	Cd	sl	2.5Y 4/4	24"	7.5YR 5/8	5%	10	10	massive	firm	
85-100	CR										

Additional Notes: Saprolite at 85”,

Commonwealth of Massachusetts
City/Town of Everytown

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

D. Determination of High Groundwater Elevation

1. Method Used: Obs. Hole #1 | Obs. Hole #1

	Obs. Hole #1	Obs. Hole #1
☐ Depth observed standing water in observation hole	______ inches	______ inches
☐ Depth weeping from side of observation hole	______ inches	______ inches
☒ Depth to soil redoximorphic features (mottles)	39 inches	24 inches
☐ Depth to adjusted seasonal high groundwater (S_h) (USGS methodology)	______ inches	______ inches

______________________ Index Well Number ______________________ Reading Date

$S_h = S_c - [S_r \times (OW_c - OW_{max})/OW_r]$

Obs. Hole/Well# ______ S_c ______ S_r ______ OW_c ______ OW_{max} ______ OW_r ______ S_h ______

2. Estimated Depth to High Groundwater: 24 inches

E. Depth of Pervious Material

1. Depth of Naturally Occurring Pervious Material

a. Does at least four feet of naturally occurring pervious material exist in all areas observed throughout the area proposed for the soil absorption system?

☒ Yes ☐ No

b. If yes, at what depth was it observed (exclude A and O Horizons)? Upper boundary: 10 inches Lower boundary: 85 inches

c. If no, at what depth was impervious material observed? Upper boundary: ______ inches Lower boundary: ______ inches

Commonwealth of Massachusetts
City/Town of Everytown

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

F. Certification

I certify that I am currently approved by the Department of Environmental Protection pursuant to 310 CMR 15.017 to conduct soil evaluations and that the above analysis has been performed by me consistent with the required training, expertise and experience described in 310 CMR 15.017. I further certify that the results of my soil evaluation, as indicated in the attached Soil Evaluation Form, are accurate and in accordance with 310 CMR 15.100 through 15.107.

	3/21/2018
Signature of Soil Evaluator	Date
I.M. Soil Evaluator	6/30/2019
Typed or Printed Name of Soil Evaluator / License #	Expiration Date of License
Sandy Loam	Everytown Board of Health
Name of Approving Authority Witness	Approving Authority

Note: In accordance with 310 CMR 15.018(2) this form must be submitted to the approving authority within 60 days of the date of field testing, and to the designer and the property owner with Percolation Test Form 12.

Field Diagrams: Use this area for field diagrams:

APPENDIX C

SAMPLE FORM 12

Commonwealth of Massachusetts
City/Town of Hometown USA
Percolation Test
Form 12

Percolation test results must be submitted with the Soil Suitability Assessment for On-site Sewage Disposal. DEP has provided this form for use by local Boards of Health. Other forms may be used, but the information must be substantially the same as that provided here. Before using this form, check with the local Board of Health to determine the form they use.

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

A. Site Information

Potential New Homeowner
Owner Name

82 Main Street
Street Address or Lot #

City/Town	State	Zip Code
Hometown	MA	11111

Contact Person (if different from Owner)	Telephone Number

B. Test Results

	Date: 7-11-2016	Time: 11:34	Date: 7/11/2016	Time: 12:29
Observation Hole #	2A		3A	
Depth of Perc	26"		27"	
Start Pre-Soak	11:34		12:27	
End Pre-Soak	11:49		12:42	
Time at 12”	11:49		12:42	
Time at 9”	11:54		12:48	
Time at 6”	12:01		12:57	
Time (9”-6”)	7 minutes		9 minutes	
Rate (Min./Inch)	3 min per inch		3 min per inch	
	Test Passed: ☒		Test Passed: ☒	
	Test Failed: ☐		Test Failed: ☐	

I M A Soil Evaluator
Test Performed By:

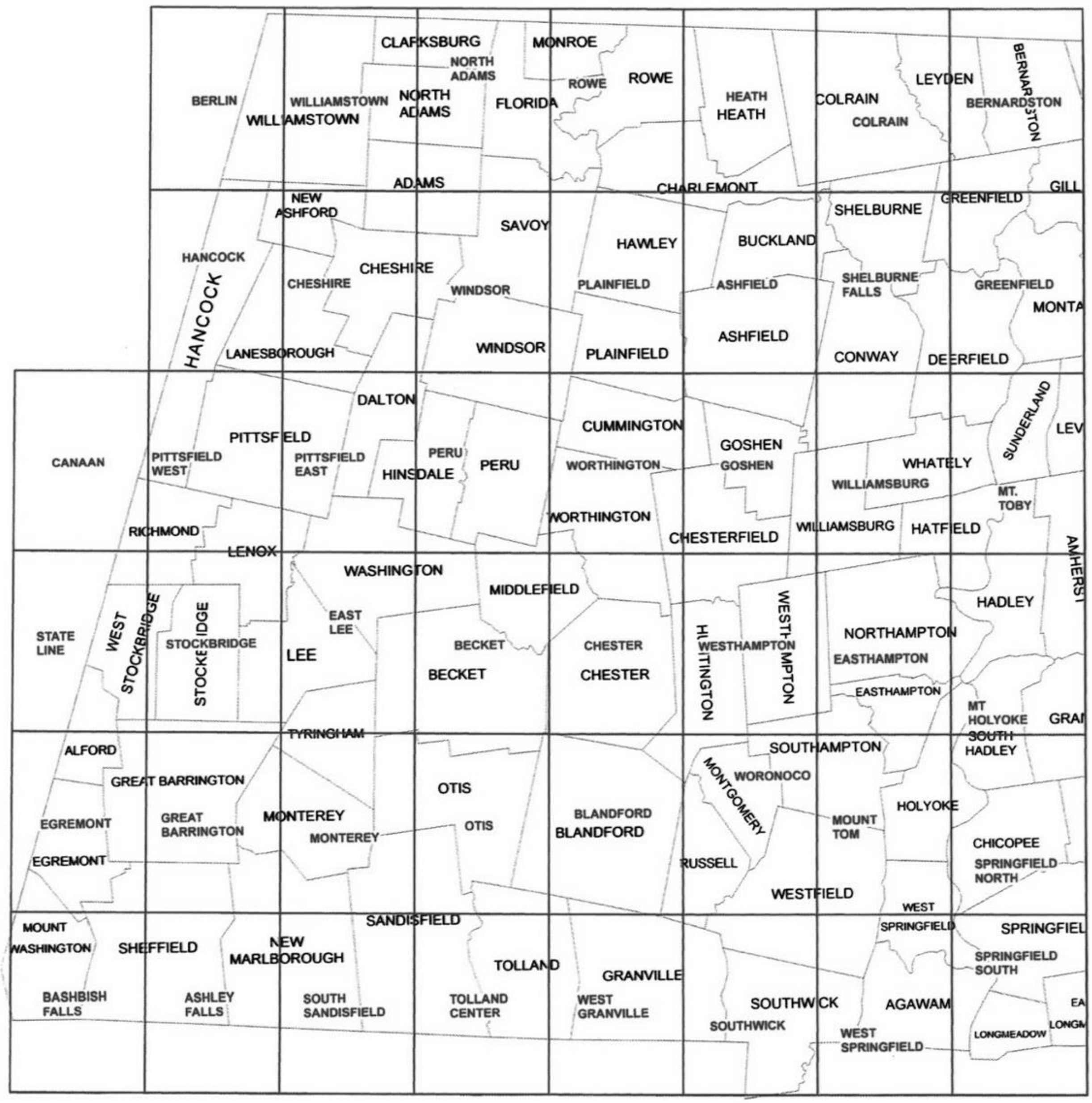
Seen It All
Witnessed By:

Comments:

APPENDIX D

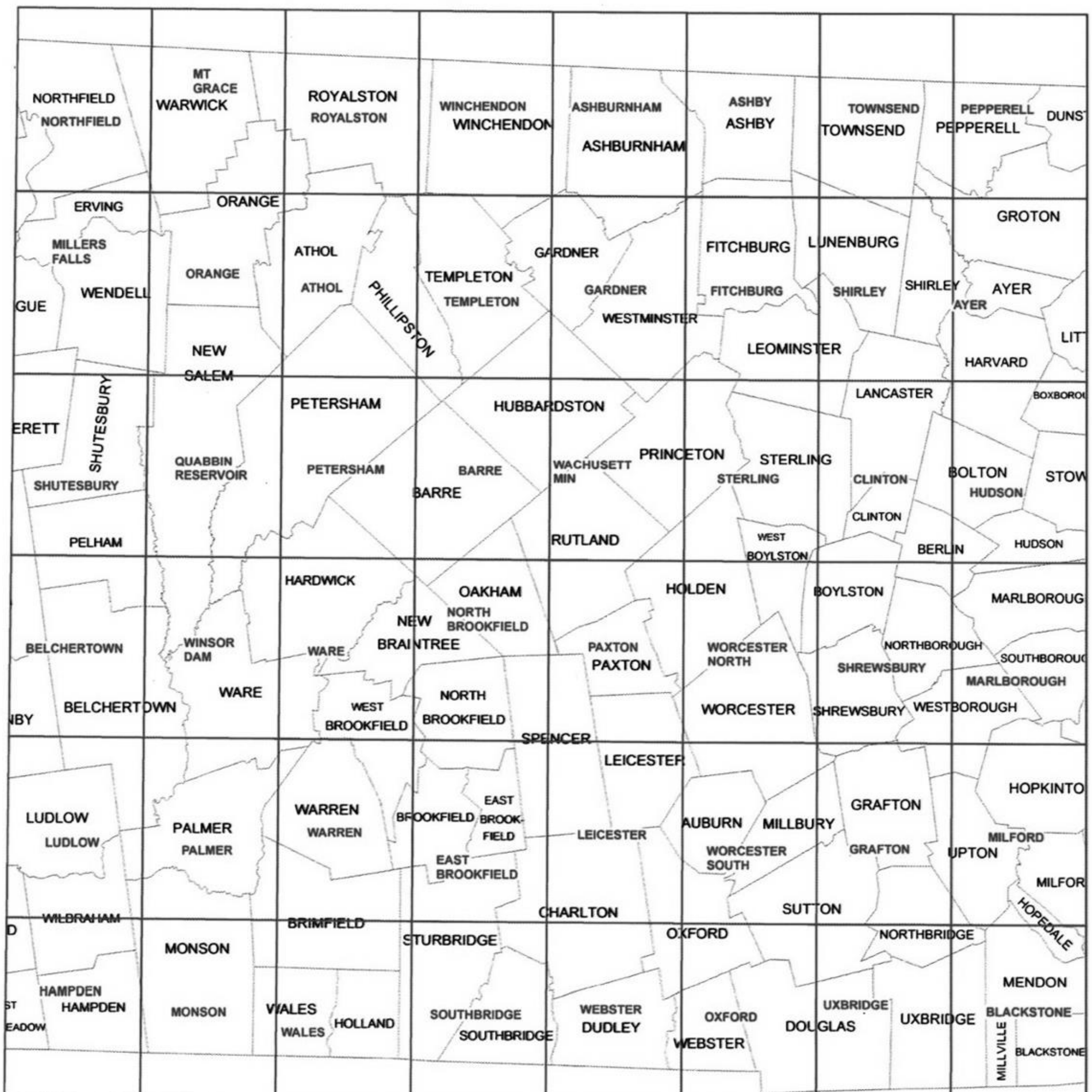
MASSACHUSETTS
USGS QUADRANGLES

Western MA



CLARKSBURG
MONROE
NORTH ADAMS
ROWE
BERLIN
WILLIAMSTOWN
FLORIDA
HEATH
COLRAIN
LEYDEN
BERNARDSTON
ADAMS
CHARLEMONT
GILL
NEW ASHFORD
SAVOY
HAWLEY
BUCKLAND
SHELBURNE
GREENFIELD
HANCOCK
CHESHIRE
WINDSOR
PLAINFIELD
ASHFIELD
SHELBURNE FALLS
MONTA
LANESBOROUGH
CONWAY
DEERFIELD
DALTON
CUMMINGTON
SUNDERLAND
LEV
PITTSFIELD
GOSHEN
CANAAN
PITTSFIELD WEST
PITTSFIELD EAST
PERU
HINSDALE
WORTHINGTON
WHATELY
WILLIAMSBURG
MT. TOBY
RICHMOND
CHESTERFIELD
HATFIELD
LENOX
AMHERST
WASHINGTON
MIDDLEFIELD
HADLEY
EAST LEE
STATE LINE
WEST STOCKBRIDGE
STOCKBRIDGE
LEE
BECKET
CHESTER
HUNTINGTON
WESTHAMPTON
NORTHAMPTON
EASTHAMPTON
MT HOLYOKE
GRA
TYRINGHAM
SOUTH HADLEY
ALFORD
SOUTHAMPTON
GREAT BARRINGTON
WORONOCO
OTIS
MONTGOMERY
HOLYOKE
EGREMONT
MONTEREY
BLANDFORD
MOUNT TOM
CHICOPEE
SPRINGFIELD NORTH
RUSSELL
WESTFIELD
WEST SPRINGFIELD
SANDISFIELD
SPRINGFIEL
MOUNT WASHINGTON
SHEFFIELD
NEW MARLBOROUGH
TOLLAND
GRANVILLE
SPRINGFIELD SOUTH
BASHBISH FALLS
ASHLEY FALLS
SOUTH SANDISFIELD
TOLLAND CENTER
WEST GRANVILLE
SOUTHWICK
AGAWAM
EA
LONGMEADOW
LONG

Central MA



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NORTHFIELD
MT GRACE
WARWICK
ROYALSTON
ROYALSTON
WINCHENDON
WINCHENDON
ASHBURNHAM
ASHBURNHAM
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ASHBY
TOWNSEND
TOWNSEND
PEPPERELL
PEPPERELL
ERVING
ORANGE
MILLERS FALLS
WENDELL
ORANGE
ATHOL
ATHOL
PHILLIPSTON
TEMPLETON
TEMPLETON
GARDNER
GARDNER
WESTMINSTER
FITCHBURG
FITCHBURG
LUNENBURG
SHIRLEY
SHIRLEY
GROTON
AYER
AYER
NEW SALEM
LEOMINSTER
HARVARD
SHUTESBURY
PETERSHAM
HUBBARDSTON
LANCASTER
QUABBIN RESERVOIR
PETERSHAM
BARRE
BARRE
WACHUSETT MIN
PRINCETON
STERLING
STERLING
CLINTON
CLINTON
BOLTON
HUDSON
SHUTESBURY
PELHAM
RUTLAND
WEST BOYLSTON
BERLIN
HUDSON
HARDWICK
OAKHAM
HOLDEN
BOYLSTON
NEW BRAINTREE
NORTH BROOKFIELD
BELCHERTOWN
WINSOR DAM
WARE
PAXTON
PAXTON
WORCESTER NORTH
NORTHBOROUGH
SHREWSBURY
MARLBOROUGH
BELCHERTOWN
WARE
WEST BROOKFIELD
NORTH BROOKFIELD
SPENCER
WORCESTER
SHREWSBURY
WESTBOROUGH
LEICESTER
LUDLOW
LUDLOW
PALMER
PALMER
WARREN
WARREN
BROOKFIELD
EAST BROOKFIELD
EAST BROOKFIELD
LEICESTER
AUBURN
MILLBURY
WORCESTER SOUTH
GRAFTON
GRAFTON
UPTON
MILFORD
WILBRAHAM
BRIMFIELD
CHARLTON
SUTTON
HOPEDALE
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SOUTHBRIDGE
WEBSTER
DUDLEY
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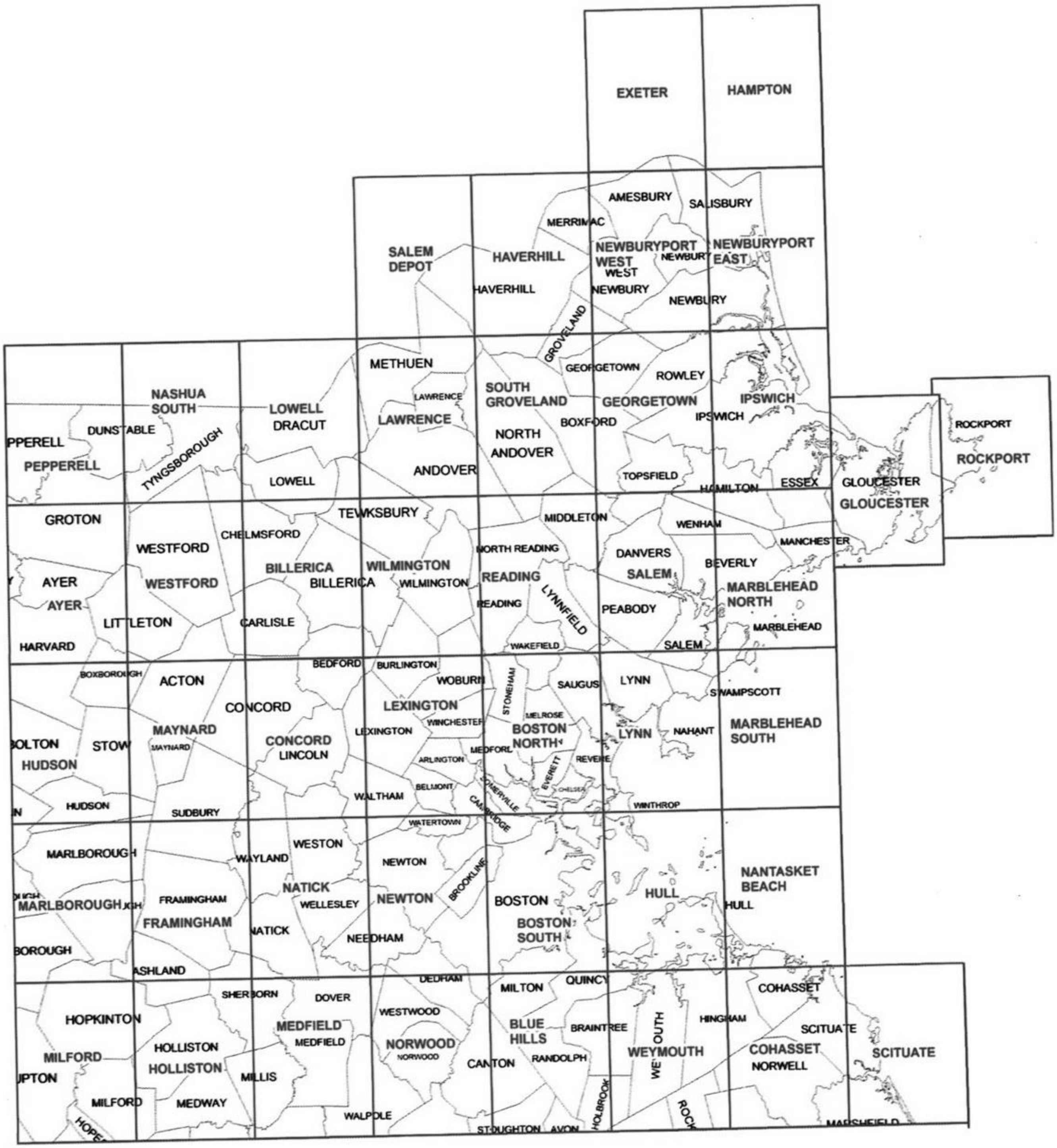
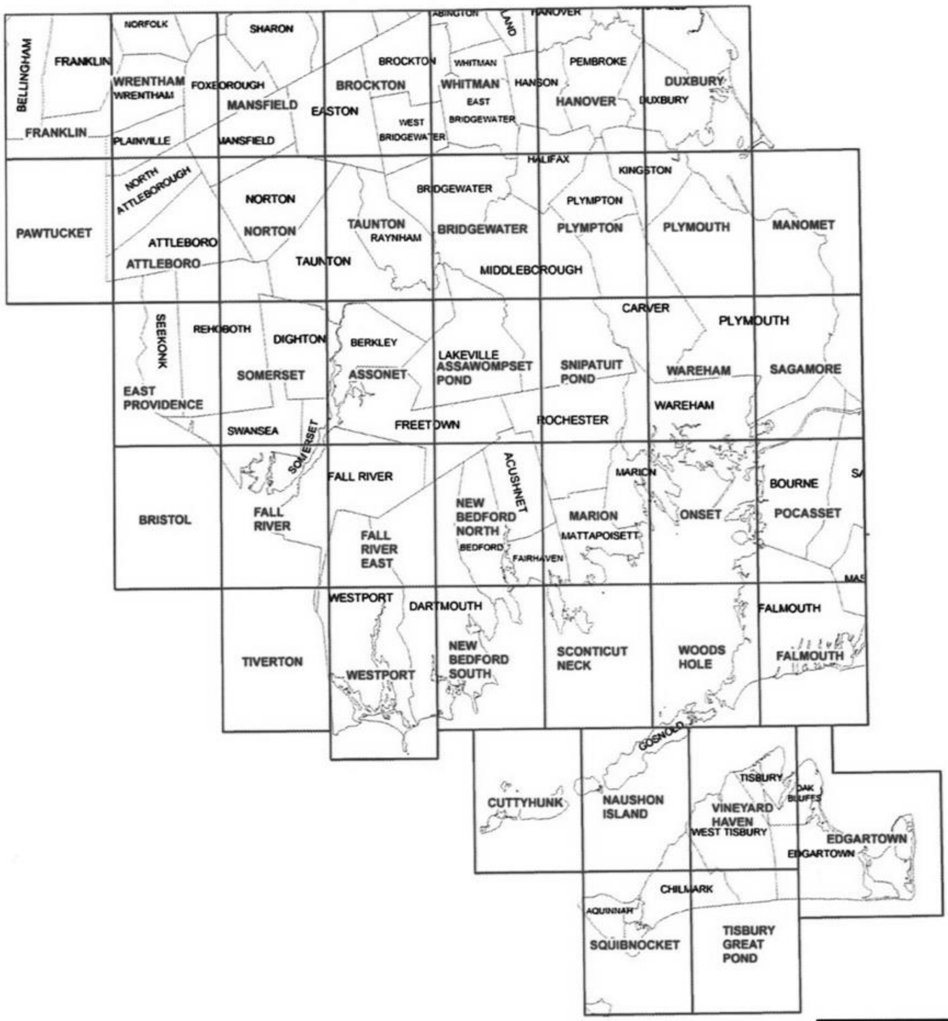
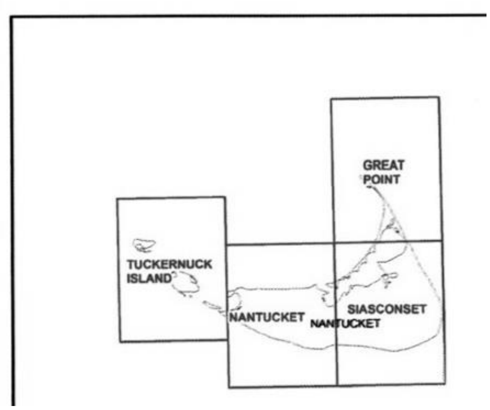
UXBRIDGE
UXBRIDGE
MENDON
BLACKSTONE
MILLVILLE
BLACKSTONE

Northeastern MA

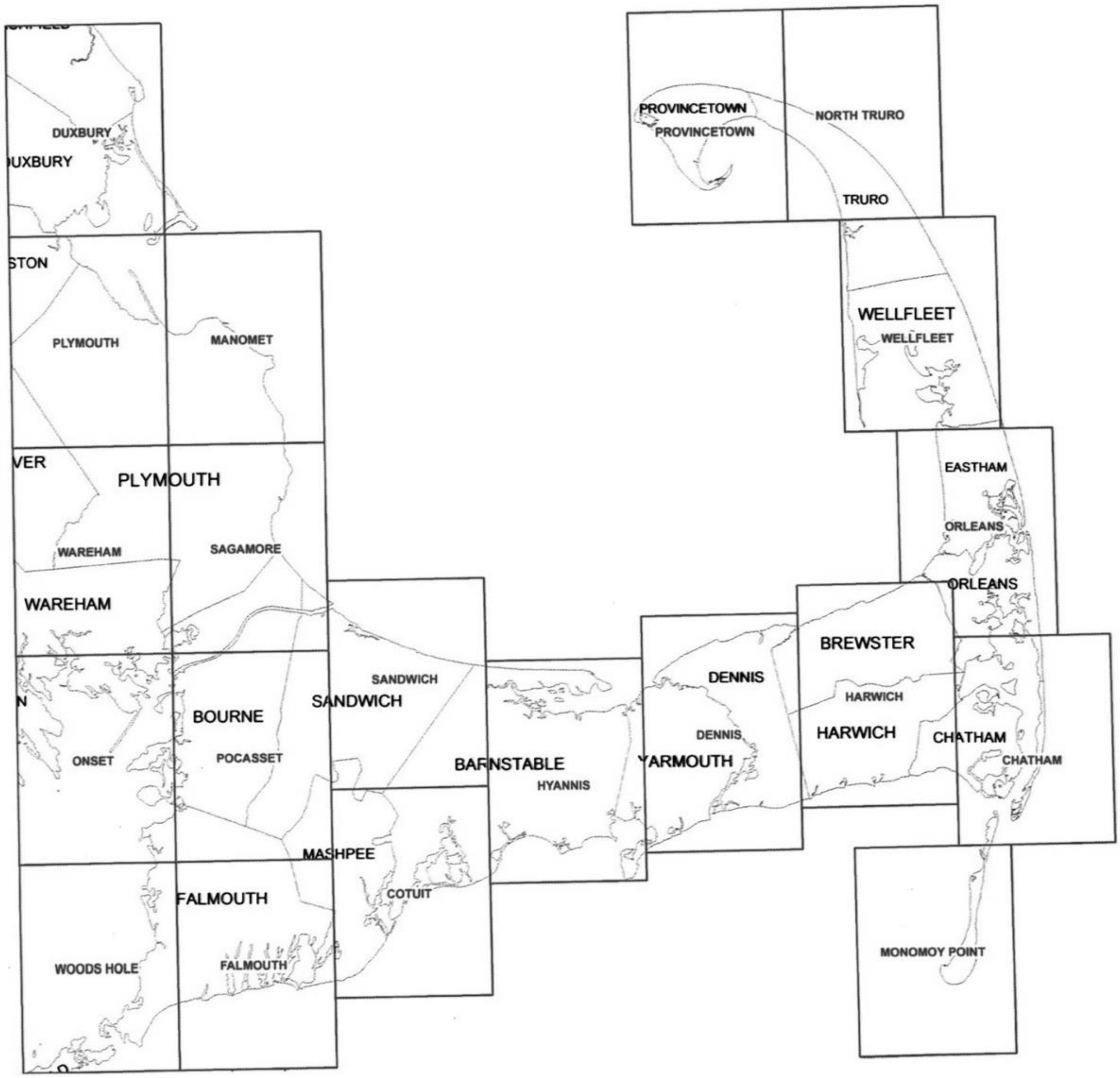


Southeastern MA & Islands





Cape Cod


PROVINCETOWN
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VER
PLYMOUTH
EASTHAM
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WAREHAM
SAGAMORE
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WAREHAM
BREWSTER
SANDWICH
DENNIS
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CHATHAM
HYANNIS
MASHPEE
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COTUIT
MONOMOY POINT
WOODS HOLE
FALMOUTH