Natural Terrain

Chapter 1

SURFACE CONFIGURATION

Maneuver commanders must have accurate intelligence on the surface configuration of the terrain. Ravines, embankments, ditches, plowed fields, boulder fields, and rice-field dikes are typical surface configurations that influence military activities. Elevations, depressions, slope, landform type, and surface roughness are some of the terrain factors that affect movement of troops, equipment, and material.

Landforms

Landforms are the physical expression of the land surface. The principal groups of landforms are plains or plateaus, hills, and mountains. Within each of these groups are surface features of a smaller size, such as flat lowlands and valleys. Each type results from the interaction of earth processes in a region with given climate and rock conditions. A complete study of a landform includes determination of its size, shape, arrangement, surface configuration, and relationship to the surrounding area.

Relief

Local relief is the difference in elevation between the points in a given area. The elevations or irregularities of a land surface are represented on graphics by contours, hypsometric tints, shading, spot elevations, and hachures.

Slope or Gradient

Slope can be expressed as the slope ratio or gradient, the angle of slope, or the percent of slope. The slope ratio is a fraction in which the vertical distance is the numerator and the horizontal distance is the denominator. The angle of slope in degrees is the angular difference the inclined surface makes with the horizontal plane. The tangent of the slope angle is determinedly dividing the vertical distance by the horizontal distance between the highest and lowest elevations of the inclined surface. The actual angle is found by using trigonometric tables. The percent of slope is the number of meters of elevation per 100 meters of horizontal distance. Slope information that is available to the analyst in degrees or in ratio values may be converted to percent of slope by using a nomogram.

VEGETATION FEATURES

Plant cover can affect military tactics, decisions, and operations. Perhaps the most important is concealment. To make reliable evaluations when preparing vegetation overlays, analysts must collect data on the potential effects of vegetation on vehicular and foot movement, rover and concealment, observation, airdrops, and construction materials.

Types

The types of vegetation in an area can give an indication of the climatic conditions, soil, drainage, and water supply. Terrain analysts are interested in trees, scrubs and shrubs, grasses, and crops.

On military maps, any perennial vegetation high enough to conceal troops or thick enough to be a serious obstacle to free passage is classified as woods or brushwood. Although trees provide good cover and concealment, they can present problems to movement of armor and wheeled vehicles. Woods also slow down the movement of dismounted troops. Individual huge trees are seldom so close together that a tank cannot move between them, but the space between them is often filled by smaller trees or brush. Closely spaced trees are usually fairly small and can be pushed over by a tank; however, the resulting pileup of vegetation may stop the tank. Trees that can stop a wheeled vehicle are usually too closely spaced to bypass. The pileup effect from pushing over vegetation is greater for wheeled vehicles than for tanks.

Trees are classified as either deciduous (broadleaf) or coniferous (evergreen). With the exception of species growing in tropical areas and a few species existing intemperate climates, most broadleaf trees lose their leaves in the fall and become dormant until the early spring. Needleleaf trees do not normally lose their leaves and exhibit only small seasonal changes.

Woodlands or forests are classified according to the dominant local tree type. A forest is classified as either deciduous or coniferous if it contains at least 60 percent of that species. Wooded areas that contain less than a 60 percent mixture of either species are classified as a mixed forest.

Scrubs include a variety of trees that have had their growth stunted because of soil or climatic conditions. Shrubs comprise the undergrowth in open forests, but in arid and semiarid areas they are the dominant vegetation. Shrubs normally offer no serious obstacle to movement and provide good concealment from ground observation however, they may restrict fields of fire.

For terrain intelligence purposes, grass more than 1 meter high is considered tall. Grass often improves the trafficability of soils. Very tall grass may provide concealment for foot troops. Foot movement in savannah grasslands is slow and tiring; vehicular movement is easy; and observation from the air is easy.

Field crops constitute the predominant class of cultivated vegetation. Vine crops and orchards are common but not widespread, and tree plantations are found in relatively few areas. The size of cultivated areas ranges from paddies covering a quarter of an acre to vast wheat fields extending for thousands of acres.

In a densely populated agricultural area where all arable land is used for the crop producing the highest yield, it may be possible to predict the nature of the soils from information about the predominant crop. Rice, for example, requires fine-textured soils, while other crops generally must have firm, well-drained land. An area of orchards or plantations usually consists of rows of evenly spaced trees, showing evidence of planned planting. This can be distinguished on an aerial photograph. Usually such an area is free of underbrush and vines. Rice fields are flooded areas surrounded by low dikes or walls.

Some crops, such as grain, improve the trafficability of soils, while others, such as vineyards, present a tangled maze of poles and wires and create definite obstacles to vehicles and dismounted troops. Wheeled vehicles and some tracked vehicles are unable to cross flooded paddy fields, although they can negotiate them when the fields are drained and dry or frozen. Sown crops, such as wheat, barley, oats, and rye, will have a different impact on movement and concealment than those crops planted in furrows, because they are on a flat surface.

Photographic Texture

Texture is influenced by several variables, including crown shapes, tree spacing, and tree height. Texture interpretation as a means of identifying forest type requires knowledge of the texture often associated with each forest type. This knowledge is acquired through hands-on experience or the use of vegetation keys. With hands-on experience working with aerial imagery over along period of time and through the process of trial and error, an analyst can develop a mental catalog to relate texture in a given geographic area to a specific forest type.

Vegetation keys have been developed through the same trial and error process but have been documented and are available in the literature. They can be very useful in certain instances (see Chapter 3 for examples). However, one must remember that background knowledge of the area of interest is essential and most keys are specific to tree species, geographic area, time of year, film type, and photoscale. When using color or color infrared film, tone is often referred to as hue and is represented as shades of the color image.

Photographic Tone

Tone is also very important and is often applied to the problem of forest type identification. Tone is influenced primarily by stand density, reflectivity, and location of the tree stand with respect to the photographic center. When using panchromatic and black and white infrared film, photographic tone is represented by shades of gray. For example, in most regions of the world, needle leaf trees will appear darker in tone than broadleaf trees on panchromatic film given equivalent stand density. This tone difference is due to higher reflectivity of broadleaf trees in the region of the electromagnetic spectrum to which the film is sensitive.

SOIL FEATURES

Since soils vary in their ability to bear weight, their ability to withstand vehicle passes, and their ease of digging, military planners rely heavily on soil analyses. Soil type, drainage characteristics, and moisture content affect road construction, material location, and trafficability determination. The soil factor overlay breaks down the most probable soil types, characteristics, and distribution.

Describing and classifying soil normally requires exhaustive field sampling and the expertise of soil scientists. Terrain analysts, however, can produce acceptable soil factor overlays by examining maps, other factor overlays, aerial photographs, lab analyses, boring logs, and literature. The reliability of the resulting soil factor overlays will vary with the reliability of the sources used and the analyst's ability to correlate and combine the information correctly.

Determining whether a particular soil will support vehicle passage or the construction of roads and airfields is just a part of the terrain analyst's job. Since analysts also provide information on construction materials associated with roads and airfields, they need a variety of evaluation methods and a good working knowledge of the physical properties of soil.

Type Determination

For field identification and classification, soils may be grouped into five principal types: gravel, sand, silt, clay, and organic matter. These types seldom exist separately but are found in mixtures of various proportions, each contributing its characteristics to the mixture. Some soils may gain strength under traffic while others lose it.

Gravel is angular to rounded, bulky rock particles ranging in size from about 0.6 to 7.6 cm (¼ to 3 inches) in diameter. It is classified as coarse or fine; well or poorly graded; and angular, flat, or rounded. Next to solid bedrock, well-graded and compacted gravel is the most stable natural foundation material. Weather has little or no effect on its trafficability. It offers excellent traction for tracked vehicles; however, if not mixed with other soil, the loose particles may roll under pressure, hampering the movement of wheeled vehicles.

Sand consists of rock grains from shut 0.6 cm (¼ inch) and smaller. It is classified as coarse, medium, or fine, and is angular or rounded. Well-graded angular sand is desirable for concrete aggregate and for foundation material. It is easy to drain and ordinarily not affected by frost action or moisture. Analysts must be careful, however, to distinguish between a fine sand and silt. When wet enough to become compacted or when mixed with clay, sand provides excellent trafficability. Very dry, loose sand is art obstacle to vehicles, particularly on slopes. Under wet conditions, remoldable sands react to traffic as to fine-gained soils. They feel somewhat plastic rather than gritty when rolled between the fingers.

Silt consists of natural reek grains. It lacks plasticity and possesses little or no cohesion when dry. Because of silt's instability, water will cause it to become soft or to change to a "quick" condition. When dry, silt provides excellent trafficability, although it is very dusty. However, it absorbs water quickly and turns to a deep, soft mud (a quick condition), which is a definite obstacle to movement. When ground water or seepage is present, silt exposed to frost action is subject to ice accumulation and consequent heaving.

Clay generally consists of microscopic particles. Its plasticity and adhesiveness are outstanding characterisitcs. Depending on mineral composition and proportion of coarser grains, clays vary from lean (low plasticity) to fat (high plasticity). Many clays which are brittle or stiff in their undisturbed state become soft and plastic when worked. When thoroughly dry, clay provides a hard surface with excellent trafficability; however, it is seldom dry except in arid climates. It absorbs water very slowly but takes a long time to dry and is very sticky and slippery. Slopes with a clay surface are difficult or impassable, and deep ruts form rapidly on level ground. A combination of silt and clay makes a particularly poor surface when wet.

Chemically deposited and organic sediments are classified on the basis of mode and source of sedimentations. The identification of highly organic soil is relatively easy; it contains partially decayed grass, twigs, leaves, and so forth, and has a characteristic dark brown to black color, a spongy fed, and fibrous texture.

Classification

The terrain analyst uses the field classification technique to determine if the soil is fine or coarse or if it is remoldable sand. Usually the first two steps will determine the grain. If it is squeezed and rolled between the fingertips, fine-grained plastic soil will feel soft and smooth and should produce a ribbon or thread. Remoldable sands will feel coarser and more abrasive than a fine-grained material.

Unified Soil Classification System (USCS)

The Unified Soil Classification System uses a system of two-letter abbreviations to describe the soil. The primary letter identifies the predominant soil fraction. The secondary letter further describes the characteristics of the predominant soil fraction. The percent of gravel, sand, and frees provides the information necessary to choose the primary letter. See Figure 1-1.

Physical Tests

Before analysts classify soil, they must make four physical tests: gradation, liquid limit, plastic limit, and odor test.

Gradation, or grain-size distribution of a soil, is determined by a sieve analysis. A sieve analysis is the separation of soil into its fractions. It is made to determine gradation of material retained on a No. 200 sieve. It indicates whether a soil is well or poorly graded, and it will show the percentage of fines present. The sieve analysis may be performed directly on soils that may be readily separated from the coarser particles.

Sieves that military engineers commonly use have square openings and are designated as 2-, 1½-, 1-, ¾-, and ¼- inch sieves. They also use the US standard numbers 4, 10, 20, 40, 60, 100, and 200 sieves. See Figure 1-2 for an example of a sieve analysis.

PRIMARY LETTERS

- G--Gravel

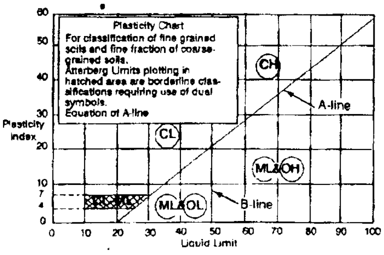
- S--Sand
- C--Clay (Used only with fine-grained soil with 50% tines or greater)
- M--Silt
- O--Organic

SECONDARY LETTERS

- W--Well graded (Used to describe sands containing less than 12% fines)
- P--Poor graded
- M--Silty Fines (Used with sands and gravels containing less than 5% but more than or equal to 50% frees)
- C--Clay-based Pines
- L--Low Compressibility (Used to describe fine-grained soils (silts, clays, organics)
- H--High Compressibility

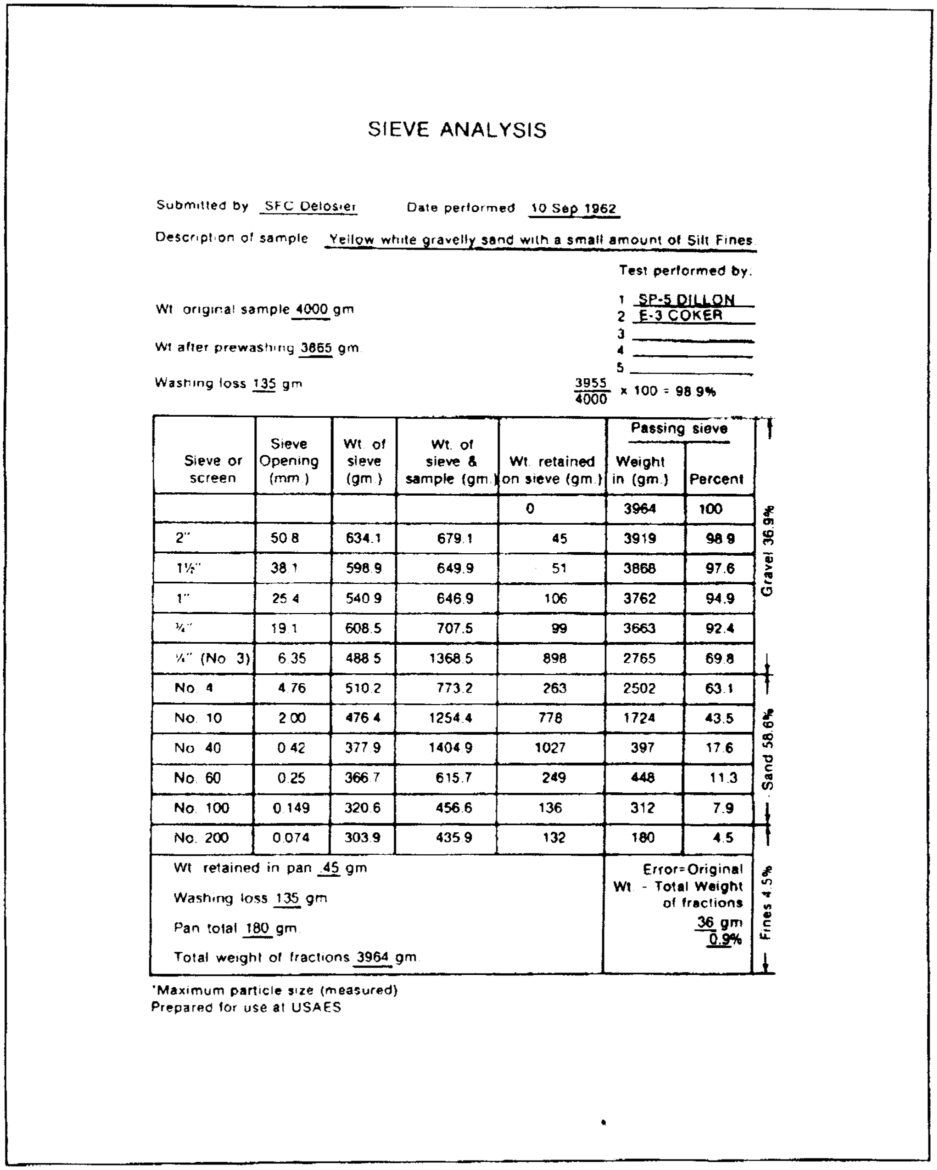
As soil becomes more moist, it transforms from a plastic to a liquid state. The liquid limit is the moisture content at which a soil will just begin to flow when jarred slightly. In conjunction with the plastic limit, it is valuable in proper identification and classification of fine-grained soils. The liquid limit is usually expressed as a whole number and is obtained by performing the Atterberg liquid limit test, which is outlined in TM 5-530.

The plastic limit is the moisture content at which cohesive soil passes from a semisolid to a plastic state. A soil or soil fraction is called plastic if, at some water

MAJOR DIVISIONS			USCS SYMBOLS	TYPICAL NAMES	CLASSIFICATION CRITERIA		
COARSE-GRAINED SOILS more than 50% retained on #200 sieve*	Gravels 50% or more of coarse fraction retained on #sieve	Clean gravels (Little or no fines)	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines Less than 5% pass #200 sieve GW, GP, SW, SP More than 12% pass #200 sieve GM, GC, SM, SC 5% to 12% pass #200 sieve Borderline classification requiring use of dual symbols	$C_U = D_{60}/D_{10}$ Greater than 4 (From Grain Size Distribution Curve) $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW	
		Gravels with fines (apprecia-ble amount of fines)	GM	Silty gravels, gravel-sand-clay mixtures		Atterberg limits plot below "A" line and plasticity index < than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index > than 7	
	Sands more than 50% of coarse fraction passes #4 sieve	Clean sands (Little or no fines)	SW	Well-graded sands and gravelly sands, little or no fines		$C_U = D_{60}/D_{10}$ Greater than 6 (From Grain Size Distribution Curve) $C_C = \frac{(D_{30})^2}{D_{10} x D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW	
		Sands with fines (apprecia-ble amount of fines)	SM	Silty sands, sand-silt mixtures		Atterberg limits plot below "A" line on plasticity chart and plasticity index <	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols e.g., SM-SC
			SC	Clayey sands, sand-clay mixtures		Atterberg limits plot above "A" line on plasticity chart and plasticity index >	
FINE-GRAINED SOILS 50% or more passes #200 sieve*	Silts And Clays liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands			
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	Silts And Clays liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts			
			CH	Inorganic clays of high plasticity fat clays			
			OH	Organic clays of medium to high plasticity			
HIGHLY ORGANIC SOILS			PT	Peat, muck, and other highly organic soils			

*Based on the material passing the 3-in (75-mm) sieve

Figure 1-1. Unified soil classification system criteria



SIEVE ANALYSIS

Submitted by SFC Delosier Date performed 10 Sep 1962

Description of sample Yellow white gravelly sand with a small amount of Silt Fines

Test performed by:

Wt original sample 4000 gm

1 SP-5 DILLON
2 E-3 COKER
3
4
5

Wt after prewashing 3865 gm

Washing loss 135 gm

$\frac{3955}{4000} \times 100 = 98.9\%$

Sieve or screen	Sieve Opening (mm.)	Wt. of sieve (gm.)	Wt. of sieve & sample (gm.)	Wt. retained on sieve (gm.)	Passing sieve	
					Weight in (gm.)	Percent
				0	3964	100
2"	50 8	634.1	679.1	45	3919	98 9
1½"	38.1	598.9	649.9	51	3868	97.6
1"	25 4	540 9	646.9	106	3762	94.9
¾"	19.1	608.5	707.5	99	3663	92.4
¼" (No 3)	6.35	488 5	1368.5	898	2765	69.8
No. 4	4.76	510.2	773.2	263	2502	63.1
No. 10	2 00	476 4	1254.4	778	1724	43.5
No 40	0 42	377.9	1404.9	1027	397	17.6
No. 60	0.25	366.7	615.7	249	448	11.3
No. 100	0.149	320.6	456.6	136	312	7.9
No. 200	0.074	303.9	435.9	132	180	4.5

Wt retained in pan 45 gm

Washing loss 135 gm

Pan total 180 gm

Total weight of fractions 3964 gm

Error=Original Wt. - Total Weight of fractions
36 gm
0.9%

'Maximum particle size (measured)
Prepared for use at USAES

Figure 1-2. Sieve analysis example

content, it can be rolled out into thin threads. The moisture content ranges between a soil sample's liquid and plastic limits. The larger the plasticity index, the more plastic the soil (PI = LL - PL). The percent of moisture content, by weight, at which a 1/8-inch diameter thread begins to crumble is expressed as a whole number when recorded

Note: Gravels will be retained at ¼ - to 2-inch sieves, sands at Numbers 4-100; all fines will be retained at the No. 200 sieve, allowing estimation of percentages of soil categories.

Since practically all fine-grained soils contain some clay, most of them will exhibit some amount of plasticity. Soil plasticity is determined by measuring the different states a plastic soil undergoes with changing moisture content. When a fine-grained soil or remoldable sand sample is rolled between two flat surfaces or between one's thumb and forefinger, it forms a thread. Highly plastic and nonplastic soils break into short lengths or cannot be formed into ribbons. In the field, analysts can examine the shape and mineral compositions of coarse-grained soil by spreading a dry sample on a flat surface, separating the gravel and frees as much as possible, and estimating the percentages of each. TM 5-530 gives further information.

Organic soils of the OL and OH groups usually have a distinct odor, which can be used to aid in identification. This color is especially apparent in fresh samples. It is gradually reduced when exposed to air, but can be brought out again by heating a wet sample.

Field Identification

Normally, laboratory equipment will not be available in the field, but analysts can estimate and tentatively classify without tests. Classifications made under stricter conditions will be more accurate. We classify soils by particle size distribution. Where these soil types occur and the amount of area they cover often determine the suitability of an area for military operations. In general, we prefer coarse-grained soils for construction and cross-country movements.

Well-graded and poorly-graded soils can usually be distinguished by comparing the sizes. Poorly-graded soils, however, are more difficult to classify because they lack one size particle. Principal aids to soil identification and classification are the shaking test, the dry strength or breaking test, and gully analysis.

Analysts performing the shaking test will alternately shake a wet portion of soil in the palm of the hand and squeeze between the fingers. Atypical inorganic silt will become livery, show free water to disappear from silt soil, and cause the sample to stiffen and crumble under increasing finger pressure. If the water content is just right, shaking the broken pieces will cause them to liquefy and flow together. The portion will change its consistency and the water on the surface will appear or disappear at a rapid, sluggish, slow, or no-reaction speed. A rapid reaction to this test is typical for a nonplastic, uniform fine sand, inorganic silt, or diatomaceous (algae-based) earths. A sluggish reaction indicates slightly plastic inorganic and organic silts, or very silty clays. An extremely slow or no reaction to the shaking test is typical for all clays that plot above the A-line on the plasticity chart as well as for highly plastic organic clays.

The dry strength test readily distinguishes between plastic clays and nonplastic silts or fine sands. Analysts perform the dry strength or breaking test only on a small portion of soil, about ½-inch thick and 1½ inches in diameter, that passes the Number 40 sieve. They prepare this by molding a portion of wet plastic soil into the size and shape desired and allowing it to air (NOT oven) dry. After the sample is thoroughly dry, they will attempt to break the soil using their thumbs and forefingers. If it breaks, they will try to powder it by rubbing the particles together. Typical reactions obtained in this test for various types of soil are--

- Very highly plastic soil, or very high dry strength. Samples cannot be broken or powdered by finger pressure.
- Highly plastic soil, or high dry strength. Samples will break with great effort, but they cannot be powdered.
- Medium plastic soil, or medium dry strength. Samples will break and powder with some effort.
- Slightly plastic soil, or low dry strength. Samples will break and powder easily.
- Nonplastic soil, or very little or no dry strength. Samples crumble and powder on being picked up.

Gullies, sometimes called head water channels, result from erosion caused by water runoff. They develop in places where water cannot easily filter into the ground; therefore, it collects and flows in rivulets across the land surface. Gully analysis can be of great assistance in determining soil types, since these rivulets often take the shape peculiar to the material over which they flow. Since fine-grained silts and clays are relatively impervious soils, many gullies develop on their surfaces. Sands and gravels are rather permeable, and few or no gullies form.

Other factors that govern the extent of gully formation in an area are climate, vegetation, ground slope, end gradient of individual gullies. Gradient is more important than intensity, or number, of gullies in revealing soil conditions. The types of gullies that may be formed in various soil types are--

- Gullies in clay. They have a long, uniform, gentle gradient and are smoothly rounded. Clay soils are impervious and cohesive and often have a well-developed gully system.
- Gullies in silt (primarily loess). They take the form of a U and have steep sides and generally flat bottoms. The gradient is steep at the head of the gully but becomes more gentle a short distance away.
- Gullies in sand-clay. They are similar to gullies in silts but are more U-shaped, with a rounded rather than flat bottom. The gradient is nearly vertical at the head of the gully but levels off rapidly to a very gentle slope.
- Gullies in gravel, sand, or well-graded mixtures with some clays. They are usually well-defined, short, straight notches (ditches). The cross section is a sharp V with a uniform gradient. The steeper gradients are associated with the coarser materials. See Figure 1-3.

WATER FEATURES

Safe water, in sufficient amounts, is strategically and tactically important to Army operations. Water that is not properly treated can spread diseases. The control of and access to water is critical for drinking, sanitation, construction, vehicle operation, and other military operations. Military planners are concerned with areas with the highest possibilities for locating usable ground water. They must consider all feasible sources and methods for developing sources when making plans for water supply. Quantity and quality are important considerations. Terrain analysts can use the methods and systems available to locate both surface and subsurface water resources.

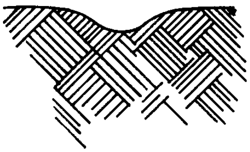
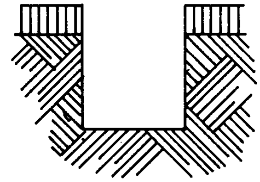
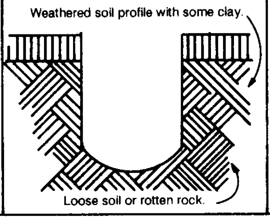
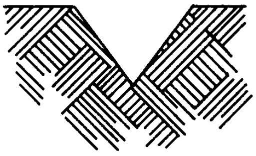
Materials	**Cross Sections**		
Cohesive Clays and silty clays. (Usually found in lake beds, marine terraces and clay-shale areas.)		Moderately Cohesive Silt. (Primarily loess and alluvial silt deposits. Also fine volcanic ash fails.)	
Moderately Cohesive Weakly cemented sand clays. (Occur in coastal plains and many bedrock areas.)		Noncohesive Granular materials. (Often found in terraces and out-wash plains.)	

Figure 1-3. Gully profiles

Quantity

Water quantity depends on the climate of the area. Plains, hills, and vegetation are good indicators of water sources.

Large springs are the best sources of water in karstic plains and plateaus. Wells may produce large amounts if they tap underground streams. Shallow wells in low-lying lava plains normally produce large quantities of ground water. In lava uplands, water is more difficult to find, wells are harder to develop, and careful prospecting is necessary to obtain adequate supplies. In wells near the seacoast, excessive withdrawal of freshwater may lower the water table, allowing infiltration of saltwater that ruins the well and the surrounding aquifer.

Springs and wells near the base of volcanic cones may yield fair quantities of water, but elsewhere in volcanic cones the ground water is too far below the surface for drilling to be practicable. Plains and plateaus in arid climates generally yield small, highly mineralized quantities of ground water. In semiarid climates, following a severe drought, an apparently dry streambed frequently may yield considerable amounts of excellent subsurface water. Ground water is abundant in the plains of humid tropical regions, but it is usually polluted. In arctic and subarctic plains, wells and springs fed by ground water above the permafrost are dependable only in summer; some of the sources freeze in winter, and subterranean channels and outlets may shift in location. Wells that penetrate aquifers within or below the permafrost are good sources of perennial supply.

Adequate supplies of ground water are hard to obtain in hills and mountains composed of gneiss, granite, and granite-like rocks. They may contain springs and shallow wells that will yield water in small amounts.

Tree species can also indicate local ground water table presence. Deciduous trees tend to have far-reaching root systems indicating a water table close to the ground surface. Coniferous trees tend to have deep root systems, which depict the ground water table as being farther away from the ground surface. In desert environments, vegetation is scant and specialized to withstand the stress of desert life. Vegetation type is dependent on the water table of that location. Palm trees indicate water within 2 or 3 feet, salt grass indicates water within 6 feet, and cottonwood and willow bees indicate water within 10 to 12 feet. The common sage, greasewood, and cactus do not indicate water levels.

Quality

Quality will vary according to the source and the season, the kind and amount of bacteria, and the presence of dissolved matter or sediment. Color, turbidity, odor, taste, mineral content, and contamination determine the quality of water. Brackish water is found in many regions throughout the world but most frequently along sea coasts or as ground water in arid or semiarid climates.

Contamination

Potable water is free from disease-causing organisms and excessive amounts of mineral and organic matter, toxic chemicals, and radioactivity. Although surface water is ordinarily more contaminated than other sources, it is commonly selected for use in the field because it is more accessible in the quantity required. Ground water is usually less contaminated than surface water and is, therefore, a more desirable water source. However, the use of ground water by combat units is usually limited unless existing wells are available. Rain, melted snow, or melted ice may be used in special instances where neither surface nor ground water is available. Water from these sources must be disinfected before drinking.

Pollution

Water may be contaminated but not polluted. Streams in inhabited regions are commonly polluted, with the sediment greatest during flood stages. Streams fed by lakes and springs with a uniform flow are usually clear and vary less in quality than do those fed mainly by surface runoff. Generally, the quality of water in large lakes is excellent, with the purity increasing with the distance from the shore. Very shallow lakes and small ponds are usually polluted.

Porosity and Permeability

The water-bearing capability of a natural material is determined by porosity and permeability. The amount of porosity depends on the number of open spaces in the material. The permeability of rock is its capacity for transmitting a fluid. Rock types vary greatly in size, number, arrangement of pore spaces, and ability to contain and yield water. The amount of permeability depends on the degree of porosity, the size and shape of the interconnections between the pores, and the extent of the pore system. The geometric shapes of gullies can help identify the degree of permeability and porosity.

Drainage

Surface

Most military problems involving surface water arise because stream drainage conditions vary not only from place to place but seasonally as well. Military planners are concerned with the flow and channel characteristics of surface waters and their effect on military operations. The water constitutes obstacles to cross-country movement or, when sufficiently frozen, it may provide movement. They also determine the types of equipment to be used in an area.

Drainage data on all of the surface water features is significant to any aspect of military operations. Commanders must know the width and depth of streams and canals; the velocity and discharge of streams; which areas are subject to flooding, or are permanently wet, densely ditched, or canalized; the location of dams; and any other drainage feature that may be significant.

Although surface drainage is considered a standard product, subsurface drainage is not. Potential ground water indicators include the following:

- Crop irrigation
- Karst topography
- Snowmelt patterns
- Wetlands
- Vegetation
- Springs
- Soil moisture
- Surface water
- Wells/Qanats
- Built-up areas (local municipalities and populus)

Surface water resources are generally more accessible and adequate in plains and plateaus than in mountains. Large amounts of good quality water can normally be obtained in coastal areas, valleys, or alluvial and glacial plains. Although large quantities are available in delta plains, the water may be brackish or salty. Water supplies are scarce on lacustrine, loess, volcanic, and karst plains. In the plains of arid regions, water usually cannot be obtained in quantities required by a modem army; much that is available is highly mineralized. In the plains and plateaus of humid tropical regions, surface water is abundant but is generally polluted and requires treatment. Perennial surface water supplies are difficult to obtain in arctic regions; in summer it is abundant but often polluted.

Subsurface

Ground water, or subsurface drainage, is obtained without difficulty from unconsolidated or poorly consolidated materials in alluvial valleys and plains, streams and coastal terraces, glacial outwash plains, and alluvial basins in mountainous regions. Areas of sedimentary and permeable igneous rocks may have fair to excellent aquifers, although they do not usually provide as much ground water as areas composed of unconsolidated materials. Large amounts of good-quality ground water may be obtained at shallow depths from the alluvial plains of valleys and coasts and in somewhat greater depths in their terraces. Aquifers underlying the surface of inland sedimentary plains and basins also provide adequate amounts of water. Abundant quantities of good-quality water generally can be obtained from shallow to deep wells in glacial plains. In loess plains and plateaus, small amounts of water may be secured from shallow wells, but these supplies are apt to fluctuate seasonally. Well water is usually clear and low in organic impurity but may be high in dissolved mineral content.

Patterns

The pattern of stream erosion usually gives an indication of rock structure and composition and an indication of whether the region is underlined by one or several rock types. The pattern can be dendritic, trellis, radial, annular, parallel, or rectangular.

The dendritic drainage pattern is a tree-like pattern composed of branching tributaries to a main stream, characteristic of essentially flat-lying and homogeneous rocks. This pattern implies that the area was originally flat and is composed of relatively uniform materials. Dendritic drainage is also typical of glacial till, tidal marshes, and localized areas in sandy coastal plains. The difference in texture or density of a dendritic pattern may help identify surface materials and organic areas.

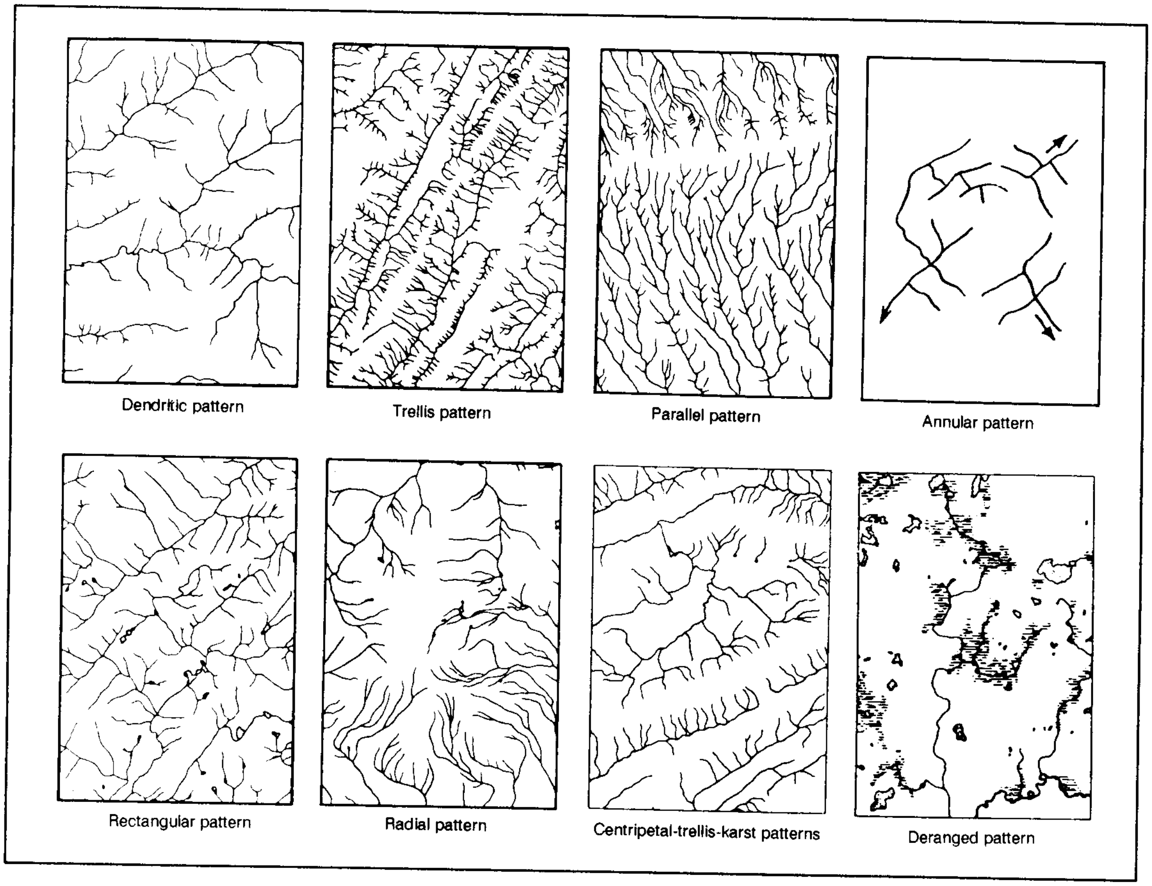
In a trellis pattern, the mainstream runs parallel, and small streams flow and join at right angles. This pattern is found in areas where sedimentary or metamorphic rocks have been folded.

In a radial pattern, streams flow outward from a high central area. This pattern is found on domes, volcanic cones, and round hills. However, the sides of a dome or volcano might have a radial drainage system while the pattern inside a volcanic cone might be centripetal, converging toward the center of the depression.

The annular pattern is a modified form of the radial drainage system, found where sedimentary rocks are upturned by a dome structure. In this pattern, streams circle around a high central area. The granitic dome drainage channels may follow a circular path around the base of the dome when it is surrounded by tilted beds.

In the parallel pattern, major streams flow side by side in the direction of the regional slope. Parallel streams are indicative of gently dipping beds or uniformly sloping topography. The greater the slope, the more nearly parallel the drainage and the straighter the flow. Local areas of lava flows often have parallel drainage, even though the regional pattern may be radial. Alluvial fans may also exhibit parallel drainage, but the pattern may be locally influenced by faults or jointing. Coastal plains, because of their slope toward the sea, develop parallel drainage overboard regions.

The rectangular drainage pattern is a specific type of angular drainage and is usually a minor pattern associated with a major type such as dendritic. This pattern is characterized by abrupt bends in streams and develops where a tree-like drainage pattern prevails over a broad region. It is caused by faulting or jointing and is generally associated with massive igneous rock. Metamorphic rock surfaces, particularly those comprised of schist and slate, commonly have rectangular drainage. Slate possesses a particularly finely textured system. Its drainage pattern is extremely angular and has easily recognizable short gullies that are locally parallel.



Dendritic pattern

Trellis pattern

Parallel pattern

Annular pattern

Rectangular pattern

Radial pattern

Centripetal-trellis-karst patterns

Deranged pattern

Figure 1-4. Typical drainage patterns

Density

A determination of the density of the drainage pattern, or the number of streams in a precise area, is very beneficial. The nature of the drainage pattern in an area will provide a strong indicator of the particle size of the soils that have developed.

Surface sediments have good internal drainage. Sandstone, for example, due to its porosity and permeability, has good internal drainage. Water can usually percolate down through the soil and underlying reck, and the surface runoff will beat a minimum. The texture or density of the drainage pattern that develops on sandstone will be coarse.

A porous reek is not necessarily permeable. Clay, for example, contains up to 90 percent water arid is very porous but is not permeable because of the nature of its flat-lying particles.

Sands and gravels are usually both porous and permeable, depending on sorting. When precipitation occurs, some of the water can percolate down through the sediment.

Shale is a relatively impermeable reek and has poor internal drainage. Surface runoff will be at a maximum, and erosion will often be intense. The texture or density of the drainage pattern that develops on shale will be fine-textured. See Figure 1-4.

OBSTACLES

Classification

An obstacle is any natural or man-made terrain feature that slows, diverts, or stops the movement of personnel or vehicles. Obstacles are classified as natural, such as escarpments, or man-made, such as built-up areas and cemeteries. They are further categorized as existing-present natural or as man-made terrain features that will limit mobility or as reinforced-existing features that man has enhanced to use as obstacles, such as gentle slopes reinforced by tank ditches, pikes, or revetments that limit mobility of maneuver units.

For classification purposes, obstacles must beat least 1.5 meters high and 250 meters long and have a slope greater than 45 percent (that which military vehicles are unable to travel). Obstacles that will be delineated should be in areas where they are of primary importance for the diversion of crosscountry movement. Obstacles include escarpments, embankments, road cuts and fills, depressions, fences, walls, hedgerows, and moats.

An obstacle factor overlay portrays linear terrain features that form natural obstacles not normally identifiable on a topographic map. Obstacles located in areas of dense forest, on steep slopes (greater than 45 percent), or within the gap width of streams normally will not be shown on the obstacle overlay. Hydrologic obstacles such as drainage ditches, channelized streams, and water banks are shown on the surface drainage overlay.

Identification

Escarpments are terrain features similar to cliffs and ridges and appear on aerial photographs as sharp breaks in the slope separating near level or gently sloping surfaces. They are hazardous to both troop and vehicle movement due to the sharp drop in the land typical of cliffs and ridges. Embankments are artificial structures, usually of earth or gravel, constructed above natural ground surfaces such as dikes, levees, and seawalls. Escarpments and embankments are tactically significant because explosive devices can make the road, railroad, or cross-country route impassable and because they can be used as channelization factors. This is especially true if the bypass capability is restrictive to the state of the ground.

Railroad and road cuts and falls restrict military movement. Cuts are thoroughfares or passages constructed through high areas. Fills are surfaces that have been built up or raised to bring a low area up to the same level as the surrounding surfaces.

Depressions are low points or sinkholes surrounded by higher ground. They usually have slopes equal to or greater than 45 percent, which will impede movement across the terrain. Pits, quarries, and sinkholes are typical examples of depressions.

Man-made features include fences or walls, hedgerows, and moats. Fences and walls are usually constructed to separate or restrict crossings from one plot of land to another. Hedgerows are tree-type barriers that can be identified by looking for closely spaced rows of trees or bushes planted on a mound. They are so dense that they restrict vehicle movement.

European vineyards offer an excellent example of obstacles, due to the wet state of the ground and the wire used to support crop growth. Combined with the existing terrain, vineyards cause extreme difficulty in cross-country mobility.

Finally, moats are landforms that appear on photos as wide trenches or ditches which usually surround a structure or prominent feature and are inaccessible to vehicles. Moats are generally restricted to the British or European areas. Preliminary identification can be made by referring to the map legend on a topographic map.