

Natural Terrain

Chapter 3

SURFACE-CONFIGURATION OVERLAY

The surface-configuration overlay is used to depict the inclined surface of the terrain and is expressed using percent of slope or change of elevation (rise) divided by the horizontal distance (run).

This overlay is one of the primary overlays used in determining the cross-country movement capability of troops and vehicles.

A 1:50,000 topographic map is required to construct a surface-configuration overlay using TTADB product specifications.

Step 1. Examine topographic maps. Construct a surface-configuration overlay for the TTADB using a standard 1:50,000 topographic map with a variety of possible contour intervals. A contour interval of 20 feet or less is preferred for constructing this overlay.

Register the overlay to the database or map you are using. Cover the selected topographic map with a clean sheet of mylar and tape them together. If the area of interest does not cover the entire map, outline the area of interest on the mylar in black pencil or ink and note the longitude and latitude or UTM coordinates at the corners.

Annotate the map sheet name and number, map series, map edition, scale, contour interval, factor overlay type (surface configuration) and classification, if required, on the overlay.

Step 2. Depict surface-drainage features. Trace the boundaries, in black pencil or ink, of all islands longer and wider than 250 meters (5 millimeters at the scale of 1:50,000). Show long, narrow islands (those less than 250 meters wide) only if they are greater than or equal to 1000 meters in length (20 millimeters on the map).

Trace the boundaries of all open-water bodies such as ponds, lakes, reservoirs, and double-lined streams in black pencil or ink. Label all open water with a **W**.

Hd = 666.6 meters (CI was in meters)

Formula: Slope category B (3 to 10%)

$$HD = \frac{20}{10} \times (100)$$

HD = 200 meters

b. Determine the map distance, or the spacing of the contour intervals, required to construct the slope calculator for categories **A** and **B**:

$$MD = \frac{HD}{D}$$

MD = map distance

HD = horizontal distance (from previous formula)

D = denominator of map scale

Slope Category A (0-3%)

$$MD = \frac{666.6}{50,000}$$

MD = .01333 meters or (13.33 mm)

Slope Category B (3-10%)

$$MD = \frac{200}{50,000}$$

MD = .004 meters or (4 mm)

Note: You must calculate map distances for each slope category outlined in TTADB product specification (PS/3JB/020) and for any slope category required for a special-purpose product.

c. Construct the slope calculator. Construct the slope calculator using the map distance calculated from the above formulas on a clear, stable-based material. Draw several ticks representing the same slope category.

d. Outline the slope categories. Analyze the contour lines on a topographic map using the slope calculator to outline and label slope categories. Slope categories are areas on a map where the slope is the same or is in the same category.

Start the slope analysis in the upper left-hand corner of the map and determine map areas whose slope (contour interval) matches the 0 to 3 percent (or lowest category required) slope category on the calculator (See Figure 3-2). When you have outlined all areas within this category using a black pencil or ink, label all outlined areas with an A or representative symbol from your legend.

Continue this analysis for all slope categories that you have outlined and labeled. Prepare the surface-configuration legend according to TTADB product specifications.

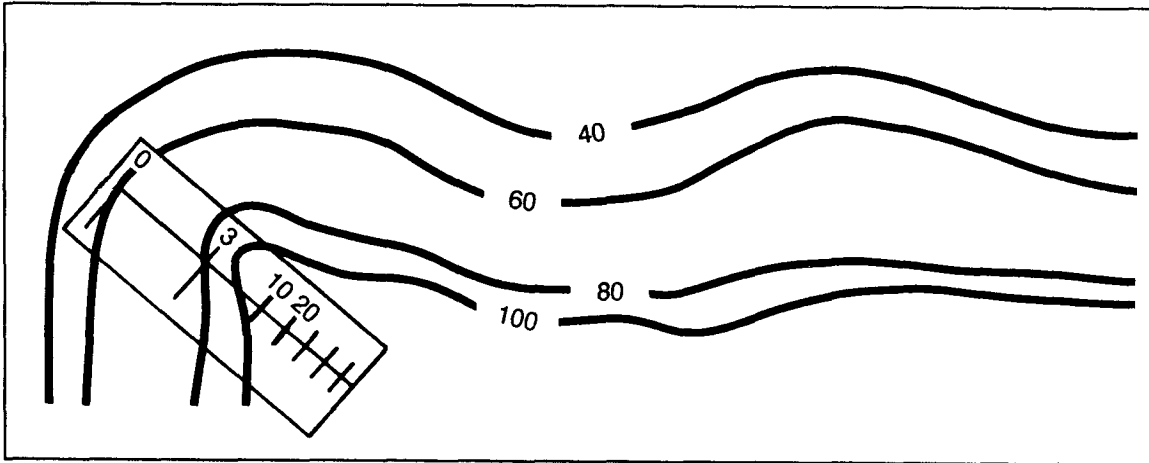


Figure 3-2. Slope example

Step 5. Determine slope from aerial photography. Determining slope from aerial photography requires complete stereo coverage. It is time-consuming and requires more skill than using a topographic map. You should use this method only if topographic maps are not available or if you need precise slope measurements from a point to a point. You cannot use this process to compile a surface-configuration factor overlay, since this overlay is keyed to a topographic base map.

Step 6. Construct the final overlay. The final step in producing a factor overlay is to put the draft manuscript overlay into a final database product. You must have support from the cartographic and reproduction elements or sections. See Chapter 8 for the final overlay procedure.

VEGETATION OVERLAY

The vegetation overlay shows natural and cultivated vegetated areas, with information about type, size, and density. This factor overlay is one of the primary overlays used in determining the cross-country movement capability of troops and equipment, cover and concealment line of sight, and location of construction resources.

A 1:50,000 topographic map and complete stereo imagery is required to construct a vegetation factor overlay using TTADB product specifications.

Step 1. Collect required collateral data. The vegetation factor overlay is one of the most complex and difficult factor overlays terrain analysts construct. No single source data can provide all of the data required to complete the vegetation factor overlay and data tables. In most cases, analysts must use different sources for different geographic areas. Unlike other factor overlays, where terrain factors are similar worldwide, geographical location, climate, soils, and the agricultural practices of the location being analyzed greatly influence the vegetation factors. Some of the major sources are maps, literature, and aerial imagery.

Military topographic maps. Standard military topographic maps differ in completeness according to scale and country of origin. The boundaries of forested areas

terrain information (EETI) required to produce the vegetation factor overlay. The data elements required are--

- Vegetation-area boundaries.
- Vegetation type.
- Height to top of canopy.
- Canopy closure.
- Stems per hectare.
- Stem diameter.
- Stem spacing.
- Ground cover.
- Height to lowest branches.
- Seasonal information.

Step 3. Prepare collateral data. Gather all available data that covers the area of interest. Examine the information to ensure completeness and accuracy, to see if some of the information is old or dated, and to see if newer sources are available. Vegetation can be influenced by man's activities and can change in a relatively short period of time.

Identify information gaps. After all available information has been gathered, superimpose it on the base map to determine areas where information does not exist or is too old to be reliable.

Submit collection requirement. If information gaps exist, determine alternate available sources and submit the appropriate collection requirement. The collection request can be for new imagery or for on-site verification of dated information.

Step 4. Prepare topographic map base. Construct the vegetation overlay for the TTADB using a standard 1:50,000 topographic map. Register the overlay to the data base or map you are using. Cover the selected topographic map with a clean sheet of mylar and tape them together. If the area of interest does not cover the entire map, outline the area of interest on the mylar in black pencil or ink and note the longitude and latitude or UTM coordinates at the corners. Annotate the map sheet name and number, map series, map edition, state, factor overlay type (vegetation) and classification, if required, on the overlay.

Prepare the data table worksheets. Trace the boundaries, in black pencil or ink, of all open-water bodies such as ponds, lakes and double-lined streams and label them with a **W**.

Trace the boundaries of all built-up areas that are longer and wider than 250 meters (5 millimeters at 1:50,000 scale). Label the outlined areas with an **X**.

Step 5. Determine vegetation types and boundaries. Trace the boundaries of all forested areas. For the working overlay, label all forested areas with a **T**. Further analysis will determine type, size, density, and internal boundaries or changes.

Trace the boundaries of all agricultural areas and label the areas with an **A**. Determine the type of crops, such as dry, wet, terraced or rotating/shifting crops and add the second agricultural code (see Figure 3-4.). The analysis of collateral data will be required to determine the second code.

Trace the boundaries of all brushlands and label them with a **B1** or **B2**, depending on the vegetation category. The analysis of collateral data will be required to determine the second code.

<u>MAP UNIT CODE</u>	<u>TYPE</u>
A1	Agriculture (dry crops)
A2	Agriculture (wet crops, rice)
A3	Agriculture (terraced crops, both wet & dry)
A4	Agriculture (shifting cultivation)
B1	Brushland (< 5m high, open to medium spacing)
B2	Brushland (< 5m high, medium to dense spacing)
C*	Coniferous/Evergreen Forest
D*	Deciduous Forest
E*	Mixed Forest (Coniferous/Deciduous)
F*	Orchard/Plantation (rubber, palm, fruit, etc.)
G1	Grassland, Pasture, Meadow
G2	Grassland with Scattered Trees, some Scrub Growth
H	Forest Clearing (cutover areas, burns, etc.)
J**	Swamp (mangrove, cypress, etc.)
J	Marsh/Bog (treeless bogs, muskegs, etc.)
K	Wetlands (L.S.I., low-lying wet areas)
L	Vineyards/Hops
M	Bamboo
N	Bare Ground
W	Open Water
X	Built-up Area

*These vegetation types are given a three digit map unit code. In addition to the letter for the type code, a second digit (number) is added as the canopy closure code, and a third digit (number) is added as the height code. See Canopy Closure (%), Height (meters), and example below.

** A second digit, representing canopy closure, is added to the swamp code.

Figure 3-4. Vegetation map codes

Trace the boundaries of all grasslands and label them with a **G1** or **G2**, depending on the vegetation category. The analysis of collateral data will be required to determine the second code.

Trace the boundaries of all swamps (**I**), marshes and bogs (**J**), and wetlands (**K**) and label them accordingly.

Step 6. Determine forest type and boundaries. Since different types of trees have different characteristics and have a major impact on cross-country mobility, on cover and concealment, and on use as engineering resources, you must determine the forest type and the transition boundary of the areas already labeled **T**.

Trace the boundary of all coniferous/evergreen forests and label them with a **C**. This forest category must contain 60 percent or more species of coniferous trees. These trees are relatively easy to place within a broad classification because they tend to have definite sizes and shapes. Shadows, crown shape (see Figures 3-5 and 3-6) and photographic tone are the most common photo interpretation keys.

Trace the boundaries of all deciduous forests and label them with a **D**. This forest category must contain 60 percent or more species of deciduous trees.

Trace the boundaries of all mixed forests and label them with an **E**. Mixed forests are those forests that do not contain 60 percent or more of either coniferous or deciduous trees.

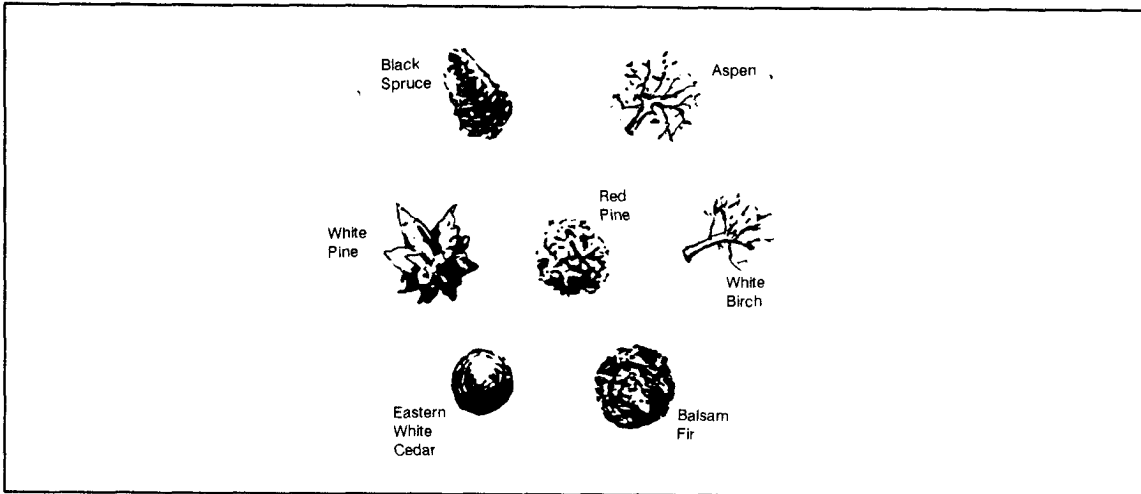


Figure 3-5. Vertical views of tree crowns

Trace the boundaries of all orchards and/or plantations and label them with a **F**. This category can be identified by the uniform rows and photographic tone and texture. Analysis of the collateral data will key analysts to look for this vegetation type and location.

Step 7. Determine canopy closure. Canopy closure is the percent of ground area covered by the tree crown and is normally computed only for forested areas. Crown area is the area covered by the vertical projection of a tree crown to the horizontal plane.

Vegetation types indicated by **C**, **D**, **E** and **F** are given two digits in addition to the letter. The letter denotes the tree type, the first number represents the canopy closure, and the second number is the height. For swamps (**I**), the third digit or height code is omitted.

Canopy closure is coded in four categories:

CODE	CANOPY CLOSURE %
1	0 - 25
2	25 - 50
3	50 - 75
4	75 - 100

Use the crown density scale to determine the canopy closure. It is made of columns of squares containing solid black circles. These circles cover and represent a percent of the area (see Figure 3-7 within the square). Match the appropriate scale to the forested area on the imagery and record the crown density for a given area.



White pine



Red pine



White spruce



Jack pine



Black spruce



Eastern hemlock



Tamarack



Balsam fir



Eastern white Cedar



White birch (old)



White birch (young)



Aspen



Basswood



Sugar maple



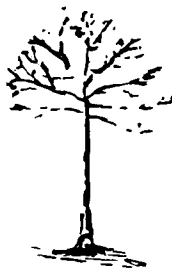
Red maple



Silver maple



Yellow birch



Beech



Oak



Balsam poplar



Ash



Elm

Figure 3-6. Silhouettes of forest trees.

Compare only the tree crown and not the shadows visible on the photo. Factors affecting accuracy of canopy closure measurements include--

Note: When tree shadows fall on level ground, they often permit identification of individual species.

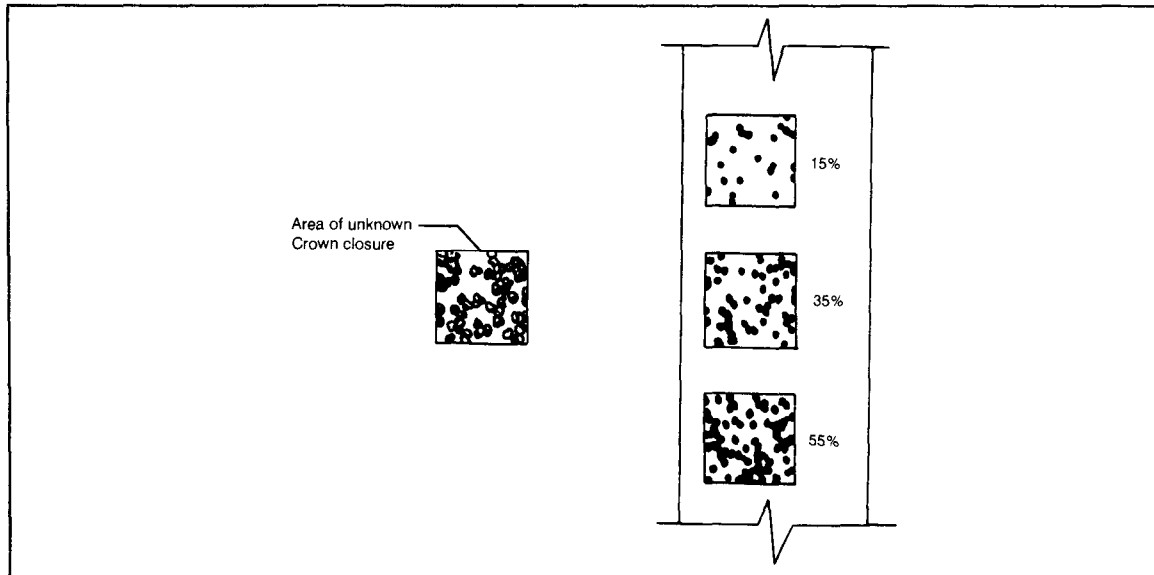


Figure 3-7. Sample crown density scale

- Image quality. Crown closure estimates of forest stands on poor quality photographs tend to be too high because of the lack of detail in photo tones and the inability of the analyst to identify small crown openings.
- Shadows. Shadows tend to mask stand openings causing the stand to appear more dense.
- Photographic scale. The minimum canopy opening that can be identified on photography is directly related to the photographic scale. Small openings which can be identified on 1:6000 scale photography cannot be seen on 1:20,000 scale photography. The net effect is to overestimate canopy closure when using small-scale photography.
- Analyst skill. An average analyst using good quality photography should produce crown closure estimates accurately to within 10 percent.

Step 8. Determine the mean height to top of canopy. The second number, or third digit, depicts the tree height (see Figure 3-8). Mean height to top of canopy is the mean or average height of a specific tree type or category. If existing data to determine and outline mean tree height does not exist, use aerial photography to measure tree height (see Chapter 9). Three methods to measure tree height from aerial photography are the parallax, shadow, and relief displacement methods. Factors affecting the accuracy of height measurements include--

- Photographic scale. Tree height measurement error generally increases when small-scale photography is used due to the inability of the analyst to identify the tree's apex.
- Character of forest. Measurement of tree height is dependent on the analyst's ability to see the ground nearby. This is closely related to the stand density and ground clearance. If a forest stand is very dense, such as a tropical rain forest, it is very difficult to find an opening large enough to permit accurate measurements.

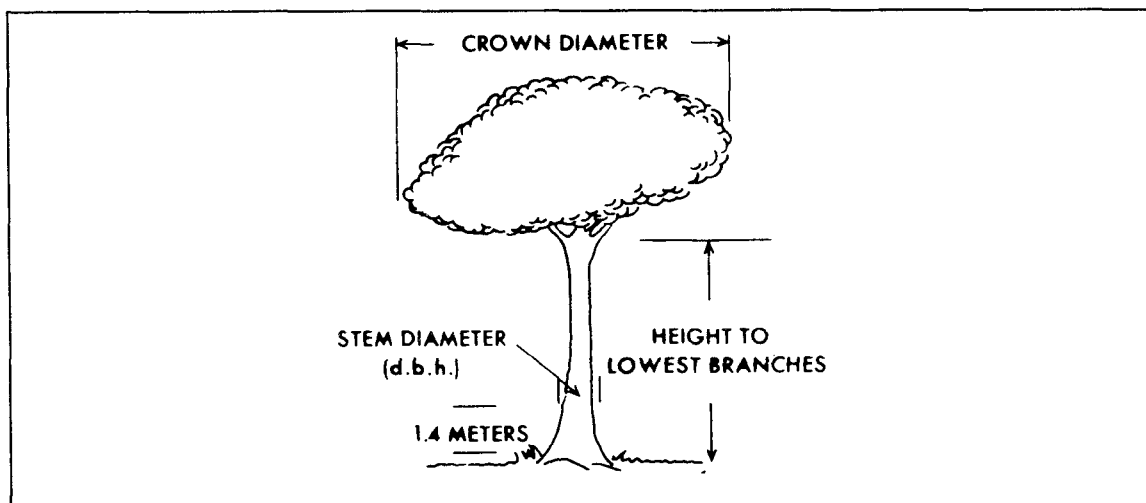


Figure 3-8. Tree mensuration

- Terrain relief. Trees growing in areas that are not level are difficult to measure accurately because of a tendency to refer measurements to canopy openings at elevations different than those at the base of the tree.
- Analyst skill. An analyst should be able to determine the height of trees accurately within each map unit. Knowledge of forest conditions and classification of specific tree type (species) can be an invaluable aid in height classification.

Step 9. Determine tree crown diameter. Tree crown diameter is the distance across the spread of a tree crown and is measured in meters. Diameter measurements of the largest, average, and smallest crowns in each category will determine the average crown diameter for a given map unit. This measurement is made using the dot-type scale or the crown micrometer wedge on the photograph (see Figure 3-9).

Select a tree for measurement. Slide the dot-type scale alongside the tree until you find a dot that is equal in size to the tree's crown. It is best not to fit the circle over the crown, because too much detail is screened by the black dot or circle.

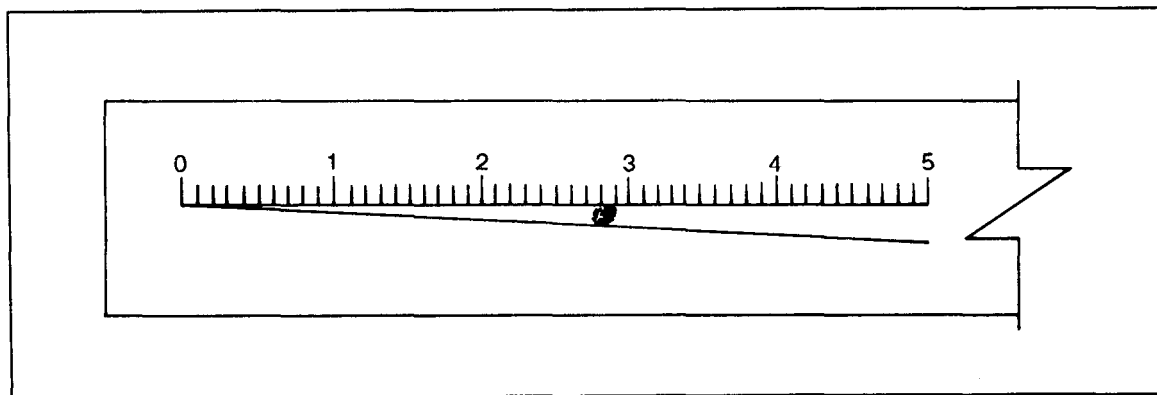


Figure 3-9. Crown micrometer wedge

Select a tree for measurement. Place the micrometer wedge so the insides of the two diverging lines are just tangent (making contact at a single point) to the tree. Take a reading at the point on the scale where the tree crown is tangent to the diverging lines.

Take an average of three measurements using either method. The answer will be in millimeters of photo distance. Convert the answer to ground distance by multiplying by the denominator of the photo scale. Convert millimeters of ground distance to meters by dividing by 1000. Factors affecting accuracy of crown diameter measurement include--

- Photographic scale. The analyst's ability to accurately identify the largest, average and smallest crowns is closely associated with the photographic scale. Small-diameter crowns cannot be detected on small-scale photographs, and clumps of closely spaced trees tend to be measured as a single crown rather than as several small ones.
- Location on the photograph. Limit tree crown measurements to the center portion of the photograph whenever possible, because the center is less affected by distortion.
- Forest density. Crown diameter measurements are most accurate in open-grown stands. Measurements in dense stands are usually limited to crown widths for dominant trees.

Step 10. Determine mean stem diameter. Tree stem diameter is the diameter of a tree at 1.4 meters (4.5 feet) above the ground. This measurement is also referred to as diameter at breast height (DBH). Calculate mean stem diameter for all vegetation units with trees 2 meters or greater in height. Record this information on the vegetation data table in centimeters.

Tree stem diameter is calculated using the mean crown diameter information obtained in step 9. If this step has not been completed, calculate the mean crown diameter for the vegetation within each map category.

When computing the stem diameter for coniferous trees, use the following formula:

$$\text{DBH (inches)} = \frac{\text{D (feet)}}{2} + 5$$

Where--

DBH (inches) = Diameter at breast height

D (feet) = Crown diameter

Example: In step 9, you have determined that a stand of coniferous trees has a mean crown diameter of 6.4 meters.

a. Convert mean crown diameter measurement to feet.

$$6.4 \text{ meters} \times 3.231 \text{ feet per meter} = 20.998 \text{ feet}$$

(Round to 21 feet)

- b. Use the above formula to determine DBH (inches).

$$\text{DBH} = \frac{21 \text{ feet}}{2} + 5 \quad \text{DBH} = 15.5 \text{ inches}$$

- c. Convert DBH (inches) to centimeters.

$$15.5 \text{ inches} \times 2.54 \text{ inches per cm} = 39.37 \text{ cm}$$

- d. Record the mean stem diameter in the vegetation table.

When computing the stem diameter for deciduous trees, use the following formula:

$$\text{DBH (inches)} = .75 \times D \text{ (feet)}$$

Example: In step 9, you have determined that a stand of deciduous trees has a mean crown diameter of 8.5 meters.

- a. Convert mean crown diameter measurement to feet.

$$8.5 \text{ meters} \times 3.281 \text{ feet per meter} = 27.885 \text{ feet}$$

(Round to 27.9 feet)

- b. Use the above formula to determine DBH (inches).

$$\text{DBH} = .75 \times 27.9$$

$$\text{DBH} = 20.925 \text{ inches}$$

- c. Convert DBH (inches) to centimeters.

$$20.925 \text{ inches} \times 2.54 \text{ inches per cm} = 53.1495 \text{ cm}$$

Round the answer to 53.15 cm.

- d. Record the mean stem diameter in the vegetation table (see Figure 3-10)

Step 11. Determine stem spacing. Stem spacing is the distance from the center of one tree to the center of the nearest adjacent tree. The easiest and fastest method to determine stem spacing is to measure directly from the photograph and convert it to ground distance (in meters).

Use the microcomparator to measure from the center of a tree stem to the center of the closest tree stem. This measurement unit depends on the scale used in the microcomparator, usually made in feet, and should be converted to meters.

If the scale is not acceptable and the distance is not measurable, use the following formula:

$$\text{SS (meters)} = \frac{12.372}{N}$$

CODE	FOREST TYPE AND CANOPY CLOSURE															
	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4	F1	F2	F3	F4
1																
2																
3						5.0 1.8 .80										
H E I G H T	4															
5																
6																
7																
8																
9																

Example D23 indicates the following: 5.0 cm — Average Stem Diameter
1.8 m — Average Tree Spacing
.80 — Vegetation Roughness

Figure 3-10. Vegetation table

Where--

- SS (meters) = Stem Spacing in meters
- 12,372 = Constant
- N = Number of trees per hectare

Before you can use this formula, you must determine N. To determine N, use the following formula:

$$N = \frac{TC \text{ (tree count in hectare scale)}}{0.08}$$

N = Number of trees per hectare
TC = Tree count in hectare scale

Determine TC (tree count in hectare scale) of a specific vegetation map code. Orient the stereopair for viewing. Place the transparent 0.08 hectare scale (see Figure 3-11) over the area using the appropriate photographic scale and count the number of trees enclosed within the circle of the hectare scale.

Convert the number of trees in a 0.08 hectare to the number of trees per hectare.

Example: 32 trees were counted within the 0.08 hectare circle using the 0.08 hectare circle template.

- a. Use the above formula to determine N.






















PHOTO SCALE	.08 HECTARE CIRCLE	CIRCLE DIAMETER	
		INCHES	MILLIMETERS
1:5,000		.253	6.38
1:6,000		.211	5.32
1:7,000		.1805	4.56
1:8,000		.158	3.99
1:9,000		.140	3.55
1:10,000		.126	3.192
1:11,000		.115	2.90
1:12,000		.105	2.66
1:13,000		.092	2.46
1:14,000		.090	2.28
1:15,000		.084	2.13
1:16,000		.079	1.99
1:17,000		.074	1.88
1:18,000		.070	1.77
1:19,000		.067	1.68
1:20,000		.063	1.60
1:21,000		.060	1.52
1:22,000		.057	1.45
1:23,000		.055	1.39
1:24,000		.053	1.33
1:25,000		.051	1.28

Figure 3-11. Sample hectare scale

$$N = \frac{32}{0.08}$$

$$N = 400$$

b. Use the above formula to determine SS, N = 400

$$SS = \frac{12.372}{400}$$

$$SS = 5.56 \text{ meters}$$

<u>MAP UNIT CODE</u>	<u>ROUGHNESS FACTOR</u>
A1	.80
B2	.95
G1	.90
G2	.60
H	.50
I	.10
J	.10
W	0
X	(not evaluated)

Figure 3-12. Vegetation roughness factors

c. Round off to the nearest 0.1 meter and record this figure in the appropriate column of the vegetation data table. Factors affecting accuracy of stem spacing measurement include--

- Tree spacing. Count only those trees that are visible from above and are sufficiently large in their exposed portion to be resolved. This problem is especially acute in tropical areas having more than one canopy.
- Photographic scale. Trees with a crown diameter of less than 0.6 meters will not be resolved at 1:12,000 scale photography. This minimum-resolved diameter increases to 1.2 meters on photo of 1:16,000 scale or smaller.
- Tree crown diameter. Tree count accuracy increases with an increase in tree crown diameter.
- Crown canopy structure. Irregularities in crown canopy tend to increase accuracy due to relief among trees.
- Terrain. If the terrain viewed in the photograph is not level, alter the area represented by a given circle or adjust the crown count to obtain the true number of trees per hectare. Compute compensation for terrain relief for every 200-foot difference in elevation.
- Analyst's skill. Inexperienced analysts may undercount the actual number of tree crowns by as much as 50 percent. For this reason, you must be careful to recognize double trees, sprout clumps, or multiple groups of trees. You can usually accomplish this by recognizing abnormally large crowns or irregularly shaped groups of crowns.

Step 12. Estimate vegetation roughness factor (VRF). The vegetation roughness factor is an estimated numerical factor that reflects the degree of vehicular speed degradation due to travel through a particular vegetation type on horizontal ground. The factor decreases from 1.0 (no speed degradation) to 0.00 (vegetation roughness does not permit off-road mobility) (see Figure 3-12). For example, grassland with little slowdown effect would have a VRF of 1.0 to 0.9, but a virtually impassable swamp with dense ground vegetation, fallen branches and trees, and exposed stumps would have a VRF of .1. The factor designated to a vegetation category is subjective and designated by the analyst. The plant's density, stem diameter, branching characteristics, root emergence, and so forth are all considered.

Step 13. Prepare the vegetation legend. Prepare the vegetation factor overlay legend according to DMA product specifications.

Step 14. Construct the final overlay. The final step in producing a factor overlay is to put the draft manuscript overlay into a final data base product. Support from the cartographic and reproduction elements/sections is required. See Chapter 8 for the final overlay procedure.

SURFACE MATERIALS ANALYSIS (SOILS)

Military planners rely heavily on soil analysis because soils vary in their ability to bear weight and withstand vehicle passes, as well as in their ease of digging. The moisture content and type of soil will affect road construction, material location, and trafficability determination. The soil factor overlay breaks down the soil types, characteristics, and distribution. Soils of the same type and quality will have similar strength and characteristics regardless of geographic location. The primary factors influencing like soil strengths are environmental changes.

Describing and classifying soil normally requires extensive field sampling and the expertise of soil scientists. The terrain analyst must be able to produce acceptable soil factor overlays by extracting information from maps, other factor overlays, aerial photographs, lab reports, boring logs, and other literature. The reliability of the soil factor overlay produced will vary with the type and reliability of the information sources. Seldom will a single source provide all of the information required.

Step 1. Collect required collateral data. Collect and analyze as many of the following sources as possible for the area of interest: maps; factor overlays; special reports, such as laboratory soil analysis reports, soil field test reports, and boring logs and well logs; literature; and aerial photographs.

The desirable scale for all source maps is 1:50,000. If 1:50,000 scale maps are not available, other existing maps should be converted to this scale.

Soil maps are produced by various organizations for specific purposes. Engineering firms may produce soil maps to support any type of construction project. Government agencies may produce soil maps for agricultural purposes, land-use planning, or special studies. The classification systems used on soil maps will vary with the producing agency and the purpose of the map. The systems must be translated into the USCS, which is the system used by the military for producing soil factor overlays. See Figure 3-13.

This table may be used as a guide in classifying soils for which no engineering test data are available. The symbol > means "greater than", the symbol < means "less than", and the symbol ≤ means "less than or equal to".			
USDA Texture Class and Symbol	Unified Symbol	AASHO Symbol	Soil Properties Related to Classifications
Clay, silty clay C, sic	CH MH CL	A-7 A-7 A-7	High shrink-swell clays Mica, iron oxide, kaolinitic clays Low LL, Generally < 45 pct clay
Silty clay loam sicl	CL ML-CL CH MH	A-7 A-7 A-7 A-7	Low LL, Plastic (A-6 if clay < 30 pct) Low LL, Moderately plastic (A-6 if clay < 30 pct) High LL, High shrink-swell clays High LL, Mica, iron oxide, kaolinitic clays
Clay loam cl	CL ML-CL CH MH	A-6 or A-7 A-6 A-7 A-7	Low LL, Plastic Low LL, Moderately plastic High LL, High shrink-swell clays High LL, Mica, iron oxide, kaolinitic clays
Loam l	ML-CL CL ML	A-4 A-6 A-4	Moderately plastic (A-6 if clay > 21 pct) Plastic (A-4 if clay < 22 pct) Low plasticity (A-7 if clay > 21 pct)
Silt loam sil	ML-CL ML CL	A-4 A-4 A-6	Moderately plastic (A-6 if clay > 21 pct) Low plasticity (A-7 if clay > 21 pct) Plastic
Silt, si	ML	A-4	Low plasticity
Sandy clay sc	CL SC	A-7 A-7	Fines > 50 pct Fines ≤ 50 pct
Sandy clay loam scl	SC SC CL	A-6 A-2-6 A-6	Plastic Fines 36-50 pct Plastic Fines ≤ 35 pct Plastic Fines > 50 pct
Sandy loam sl	SM SC SM-SC	A-2-4 or A-4 A-2-4 A-2-4	Low plasticity Plastic Moderately plastic
Fine sandy loam fsl	SM ML ML-CL SM-SC	A-4 A-4 A-4 A-4	Nonplastic Fines ≤ 50 pct Nonplastic Fines > 50 pct Moderately plastic Fines > 50 pct Moderately plastic Fines ≤ 50 pct
Very fine sandy loam vfsl	ML-CL ML	A-4 A-4	Moderately plastic Low plasticity
Loamy sands ls, lfs lvfs	SM SM-SC SM ML	A-2-4 A-2-4 A-4 A-4	Nonplastic Fines ≤ 35 pct Moderately plastic Fines ≤ 35 pct Low plasticity Fines > 35 pct Little or no plasticity
Sand, fine sand s, fs	SP-SM SM SP	A-3 A-2-4 A-3	Fines approximately 5-10 pct Fines approximately > 10 pct Fines < 5 pct
Very fine sand vfs	SM ML	A-4 A-4	Low plasticity Little or no plasticity
Coarse sand cs	SP-GW SP-SM SM SM	A-1 A-1 A-1 A-2-4	Fines < 5 pct Fines 5-12 pct Fines 13-25 pct Fines > 25 pct
Gravel, G 50 pct passes No 200 50 pct of coarse passes No 4 sieve	GP-GW GM or GC GM or GC GM GC	A-1 A-1 A-2 A-4 A-6	Fines < 5 pct Fines 5-25 pct Fines 26-35 pct Fines > 35 pct Fines > 35 pct

Figure 3-13. General relationship of systems used for classifying soil samples

Some vegetation features symbolized on topographic maps can provide clues to soil characteristics. Contours and land-use patterns can help define landforms and identify soil types. See Figure 3-14.

Geological maps may or may not be useful form soil analysis. Those maps which show the surface profile to bedrock usually define the type and depth of soil, as well as the parent material or bedrock.

In some cases, vegetation (or change of vegetation) can be an indicator of a specific soil type, change of soil type, or change of soil depth.

Climatic maps provide annual variations in temperature and moisture conditions. Of particular interest is information concerning the state of ground; for example, wet, dry, moist or frozen. This information is important in determining the stability of a soil or changes of stability with seasonal changes.

Literature reports are published by academic institutions, government agencies, or private firms on soil-related subjects such as soil, topography, geology, and vegetation.

Analysis of air photographs is the best overall method for obtaining soil information for large and inaccessible areas.

Step 2. Determine data elements. Once you have identified and collected the sources of information, determine the data elements, or EETI, required to produce the soils factor overlay. The data elements required are--

- The soil profile, which is a description of the soil with depth, including identification of soil layers; depth ranges for each horizon layer in

Landform/Bedrock	Climate	Commonly Associated Soils	
		Horizon	USCS Symbol
Sandstone	unspecified	surface (A) parent material (C)	SM, SM-SC, ML, SP, SW SM, SM-SC, GM, SC, GC, ML
	humid	A	SM
		B	SM, GM
C		SM-GM	
Shale	unspecified	surface (A) parent material (C)	CH, CL, CL-CH ML, CL, MH, CH, CL-CH, SC CL-SC, GC
	semi arid or humid	A	CL, CH
		B	CL, SC, CL-SC
C		CL, SC	
Limestone	unspecified	surface (A) parent material (C)	ML-CL, ML, CL, GM CL, CH, MH, ML, CH-MH ML-CL

Derived from D.S. Way, Terrain Analysis: A Guide to Site Selection Using Aerial Photographic Interpretation, 2nd Ed., McGraw-Hill Book Co., N.Y. 1978 and modifications to Way made by A. Reimer, ETL-TAC, 1979 & O. Mintzer, Ohio State, 1979.

Figure 3-14. Landforms and commonly associated soils

Landform/Bedrock		Climate	Commonly Associated Soils	
			Horizon	USCS Symbol
Limestone (continued)		tropical	lower horizons (B & C)	CH, MH, GC, GM
		humid		A ML-CL
				B CH
Interbedded, sandstone shale, limestone				C CH
	Flat-lying	unspecified	unspecified	CL, ML, CH, MH, ML-CL SC, GM, SM,
	Tilted	unspecified	unspecified	ML, MH, ML-CL
Intrusive	Granitic rock*	unspecified	surface (A) subsurface (B)	SM, ML, SC, ML-CL SC, CH, CL, CL-CH
	Granite	humid		A SM, ML, CL B SC C SC, CL
Extrusive, Basaltic & Volcanic		humid		A ML, CL
		tropical or subtropical		B CH, MH C ML-MH, MH, CH
		arid		A ML-CL, ML, GM B CH, CL, MH, ML-CL, GC
Slate		unspecified	unspecified	GM, GC, GM-GC
		humid		A SM
				B SM, ML-CL C SM, GM
Schist		humid		A SM, SC B MH-CH C SM, ML-CL, ML
Gneiss		humid		A SM, SM-SC, ML-CL, ML
				B MH, CH, SC
				C SM, ML CL, MH-CH, ML-CL MH,CH
Glacial Tilt/Ground Moraine		humid/derived from soft sedimentary rock		A ML, CL, ML-CL, OL
				B CL, CH, CL-CH C CL, CH, ML Note: A much wider range of texture is possible as in North Central U.S.A.
		humid/derived from igneous-metamorphic rock (crystalline)		A SM, ML, SC
				B SM, ML C SM, ML, GM Note: A much wider range of texture is possible as in North Central U.S.A.
Glacial/Moraines		humid/derived from soft sedimentary rock		A CL, ML, CL-CH, CH, GM, GC
				B CL, CH, GC
				C CL, CH, GC
		humid/derived from igneous-metamorphic rock (crystalline)		A SM-SP
	B GW, GC-GP, SC-SP			
	C SM-SC, SW, SP, GM, GC, SM, SC			

Figure 3-14 continued. Landforms and commonly associated soils

Landform/Bedrock	Climate	Commonly Associated Soils		
		Horizon	USCS Symbol	
Drumlins	unspecified/ derived from soft sedimentary rock	surface or subsurface (A or B)	ML, ML-CL, GM, GC	
		C	CL, GM, GC	
	humid/derived from igneous- metamorphic rock (crystalline)	A B C	GM-GC, SM GM-GC, SM GM, SM-SC, ML	
Eskers	unspecified	unspecified	GM, GM-GC, GP, SP, GW, SW SW-SM	
Kames	unspecified	unspecified	GP, SP, GP-GM, GM, GM-GC SM-SC, SP-SM, SM	
Glacial Outwash	unspecified	unspecified	GW, SW, GP, SP, GM, SM CL, GM-GC	
Silt/Clay Lakebeds	unspecified	A	ML-CL, CH	
		B	CL-CH	
		C	CL-CH, ML-CL, MH-CH	
Sandy Lakebeds	unspecified	unspecified	SM, ML, ML-MH, ML-CL	
Sand Dunes	unstabllized	no horizons	SP	
	stabilized	surface (A) parent mat (C)	SM, SP SP	
Loess deposits	unspecified	unspecified	ML, ML-CL, CL	
			semi arid	A B C
			ML-CL ML-CL ML-CL	
Flood Plains	braided channels	unspecified	unspecified	GW, SP
	point bars	unspecified	unspecified	SW, SP, GW
	natural levees	unspecified	unspecified	SM, ML
	slack water	unspecified	unspecified	ML, CL, MH, CH, MH-CH
	swamps depressions	unspecified	unspecified	OL, OH, PT, ML, CL, CH
	terrace	unspecified	surface subsurface	ML SC, GW, GP
Deltas	Arc delta	unspecified	surface (A) subsurface (B)	ML, CL, MH, CH GP, SP, GM, GC, SM, SC, GM-GC
		humid	A B C	ML absent GM-GC
	Bird's-foot delta	unspecified	A B C	OH CH-OH CH
Alluvial fans	unspecified	unspecified	GP, SP, SW, GW, GM, GC SM, SC, ML, CL	
			semi arid	A B C

Figure 3-14 continued. Land forms and commonly associated soils

Landform/Bedrock	Climate	Commonly Associated Soils	
		Horizon	USCS Symbol
Valley fills	unspecified	unspecified	GP, SP, GW, SW, GM, GC SM, SC, CL, ML, CL-CH, CH
	semi arid	A B C	SM SM ML-SM, SM, GM, SM, ML
Continental alluvium	unspecified	unspecified	CL, SC, CL-CH, CH
	semi arid	A B C	CL CL CL
Playas	unspecified	unspecified	ML, CL, SM, SC, MH, CH
Swamps, Bogs & Marshes	unspecified	unspecified	PT, OH, CH, MH, OL
Coastal Plain Uplands	unspecified	subsurface (A) subsurface (B)	SM, SP-SM SM, SC, SP-SM
	humid	A B C	SM SC, SM SC, SM
Coastal Plain Depressions	unspecified	unspecified	OL, ML, CL, ML-CL, MH CH, OH, PT
Beach Ridges	unspecified	surface (A) subsurface (B)	SM, GM SP, GP, GP-GM, SP-SM, SW
	humid	A B C	SM Absent SP, SM
Tidal Marsh	unspecified	surface (A) subsurface (B)	PT OL, OH, MH
Mud Flat	unspecified	unspecified	CH, CH-MH, CH-OH
Sand Flat	unspecified	unspecified	SP

Figure 3-14 continued. Landforms and commonly associated soils

*Note: *Granitic rock includes rhyolite porphyry, trachyte porphyry, dacite porphyry, basalt porphyry, augitite porphyry, granite, syenite porphyry, syenite, diorite porphyry, diorite, gabbro porphyry, gabbro, pyroxenite porphyry, pyroxentite periodotite*

meters; and identification of soil type for each horizon with one of the 15 USCS symbols.

- Depth to bedrock, or the total thickness of soil in meters.
- State-of-ground, or the average monthly moisture condition of the soil.
- Stoniness, or the estimated number of stones of a given diameter per volume of soil, which may be expressed as a percentage of the volume.
- The rating cone index (RCI), an on-site or estimated value of soil strength derived from the cone index multiplied by the remolding index.
- The cone index (CI), the field measurement indicating the shearing resistance of soil, obtained with a cone penetrometer.

- The remolding index (RI), a ratio that expresses the proportion of original strength that will be retained by a fine-grained soil or a sand with fines, poorly drained, after being subjected to vehicular traffic.

Step 3. Prepare collateral data. Gather all available soil maps that cover the area of interest. Examine their scales and legends. Extract those at 1:50,000 scale or larger that use the USCS. If any of these maps are based on field surveys (field classification), they may be used as the soil factor overlay base. Further data analysis or extraction may be unnecessary if the soil maps can produce all the information required by the data elements.

Step 4. Prepare topographic map base. Extract the topographic maps that cover the area of interest. A scale of 1:50,000 with a contour interval of 20 feet or more is preferred.

Cover the selected topographic map with a clean sheet of mylar and tape them together. If the area of interest does not cover the entire map area, outline the area of interest on the mylar in black pencil or ink and note the longitude and latitude or UTM coordinates at the corners. Register the overlay to the data base or map you are using.

Annotate the map sheet name and number, map series, map edition, scale, factor overlay type (surface materials) and classification, if required, on the overlay.

Trace the boundaries of all open-water bodies such as lakes, ponds, and double-line streams in black pencil or ink, and label them with a W.

Trace the boundaries of all built-up areas that are longer than 250 meters (5 millimeters at 1:50,000 scale). Label the outlined areas with an X.

Trace the boundaries of all permanent snowfields in black pencil or ink, and label with a them PS.

Trace the boundaries of all areas of salt evaporators and salt encrustation in black pencil or ink, and label them with an EV.

Step 5. Determine soil types and boundaries. Evaluate collateral source material for soil boundaries and types. If data does not already exist, analyze landforms, vegetation, and geology information to determine USCS type and boundary.

Trace the boundaries of all areas of exposed bedrock or void of surface soils in black pencil or ink, and label them with an RK.

Evaluate the soil factors and place appropriate boundaries on the overlay in black pencil or ink, using the topographic map as a base.

Label all evaluated areas with the appropriate USCS symbol. If information conflicts exist between different source materials, use the most reliable and current information available. Assign to each different area (soil type) a map unit number, numbering from top to bottom and left to right. Areas with the same surface soil type and identical horizon information will have the same map unit number. Do not assign map unit numbers to RK, PS, EV, X and W areas. The third digit after the USCS symbol shows the surface roughness factor.

EXAMPLE

TRAFFICABILITY TEST DATA								
PROJECT LOCATION PDG 488519				TYPE OF VEHICLE M26A1, TRK, TRACTOR, 6x6				
CONE INDEX VALUES								
		DIAL READINGS AT DEPTH						
TEST NUMBERS	0"	6"	12"	18"	24"			
1	48	56	64	70				
2	42	50	58	64				
3	41	49	57	63				
4	46	54	62	68				
5	47	53	60	66				
AVERAGE	44.8	52.4	60.2	66.2				
CI ₁ = Normal Abnormal		49	56	63				
CI ₅₀ = 56								
CRITICAL LAYER FOR 1 VEHICLE 0-6"				CRITICAL LAYER FOR 50 VEHICLES 6-12"				
REMODELING INDEX VALUES								
DEPTH	LAYER 0-6"		LAYER 6-12"		LAYER		LAYER	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
0"	57	50	54	47				
1"	59	53	56	50				
2"	62	55	59	51				
3"	66	57	64	53				
4"	71	59	67	54				
AVERAGE	63.0	54.8	60.0	51.0				
RI = $\frac{A}{B}$	$\frac{54.8}{63.0} = .869$		$\frac{51.0}{60.0} = .850$					
REMODELING INDEX FOR 1 VEHICLE .87				REMODELING INDEX FOR 50 VEHICLES .85				
RATING CONE INDEX				NOTES: 1. Soil Condition: MOIST 2. Weather Conditions: FAIR				
RCI ₁ = CI ₁ X RI ₁ = 49 x .87 = 43								
RCI ₅₀ = CI ₅₀ X RI ₅₀ = 56 x .85 = 48								
VEHICLE CONE INDEX								
VCI ₁ = 35		VCI ₅₀ = 79		Will 1 vehicle pass ?		YES _____		
				Will 50 vehicles pass ?		NO _____		
Type of soil: FG <u>XXX</u> CG _____								
Soil strenght profile: Normal <u>XXX</u> Abnormal _____								
Technician:			Computed By:			Checked By:		
Pvt. Snodgrass			C.E.P.			P.H.L.		

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Figure 3-15. Sample data table

Step 6. Determine surface roughness. Surface roughness factors are estimated factors used to compute the degree of degradation of the rate of vehicle movement caused by surface characteristics. These factors are tailored for each job by listing only those features encountered. Surface roughness is that aspect of the surface materials (such as boulder fields, gullies, and rugged bedrock.) which reduces vehicle speed.

Factors can be any number from 0.00 to 1.00 in 0.05 increments. The surface roughness factor of 1.00 for a vehicle class would indicate no degradation while a 0.80 factor would degrade vehicle speed by 20 percent. In estimating the magnitude of the factor, consider all physical characteristics of the feature as well as vehicle characteristics such as ground clearance and wheel size.

Surface roughness is classified for five types of movement categories: medium and large tanks, large wheeled vehicles, small wheeled vehicles, small tracked vehicles, and foot troops. Surface roughness factors often vary from one vehicle class to another.

Step 7. Prepare surface materials legend. Prepare a soil data table with RCI values for wet and dry seasons (see Figure 3-15). Using all available information, annotate the data elements required to complete the soil data table. This information can be used to increase the database for an area of operations.

Prepare the surface materials legend. The legend will contain only USCS soil categories with the appropriate surface roughness information. Depict additional information, such as soil depths and soil moisture from the soil data table, in the legend and within the factor overlay.

Step 8. Construct the final overlay. The final step in producing a factor overlay is to put the draft manuscript overlay into a final data-base product. Support from the cartographic and reproduction elements or sections is required. See Chapter 8 for the final overlay procedures.

OBSTACLE OVERLAY

The obstacle overlay is used to show the location and type of linear obstacles to movement. These obstacles can be either man-made or natural. This factor overlay is used with other primary factor overlays to produce cross-country mobility products and to assist military planners in developing barrier plans to tie planned obstacles into existing obstacles.

A 1:50,000 topographic map and complete stereo imagery are required to construct an obstacle factor overlay using TTADB product specifications.

Step 1. Collect required collateral data. Some of the major sources for data are maps and aerial imagery.

Standard military maps differ incompleteness and accuracy according to scale, currency and country of origin. Most existing obstacles are shown on topographic maps and can be plotted by the analyst.

Large-scale city maps can be used to plot the obstacles in and around built-up areas. The United States Geological survey (USGS) produced 1:24,000 maps show more detail than smaller scale maps. Use them as source material if they exist in your area.

Analysis of aerial imagery is the best and most accurate method of beating and plotting obstacles. Most natural obstacles, such as escarpments and embankments, are not high enough to be shown by the contour interval of a map, but they can be identified using aerial photos. Use imagery to locate and identify fences, walls, and hedgerows, which are not usually shown on standard maps.

Step 2. Prepare topographic map base. Register the overlay to the database or map you are using. Cover the selected topographic map with a clean sheet of mylar and tape them together. If the area of interest does not cover the entire map, outline the area of interest on the mylar in black pencil or ink. Mark and label the longitude and latitude or UTM coordinates of the corners.

Step 3. Identify and plot existing obstacles. Identify and plot all road and railroad cuts and fills greater than 250 meters in length and 1.5 meters in height. Start by following all of the ground lines of communication and look for areas where the terrain was altered to build a stable road or railroad. Railroads will normally have more cuts and fills to maintain a relatively flat gradient. Photo-check the cuts and falls plotted from the map and look for roads or railroads not shown on the maps. Plot the cuts and fills according to TTADB product specifications.

Identify and plot escarpments and embankments greater than 250 meters long and 1.5 meters high. Start by following all streams and rivers and look for areas where the contour lines converge. Look for areas where flat terrain transitions into more rugged, steep terrain. Photo-check these areas and mark the areas where escarpments, embankments, cliffs, ravines, and old stream banks exceed 45 percent. Plot the obstacles using the appropriate symbols.

Identify and plot depressions. Check geologic formations to determine if natural depressions are present. Sinkholes are commonly found in areas containing flat-lying limestones (karst topography) with historically wet climates. Topographic maps show most large depressions. Photo-check these areas and look for new pits, quarries, and open-pit mines. Plot all depressions which are greater than 250 meters long and 1.5 meters high and have slopes greater than 45 percent with the appropriate symbol.

Identify and plot other man-made features and any unique feature which can be classified as obstacles.

Step 4. Prepare the obstacle legend. Prepare the obstacle factor overlay legend according to DMA product specifications.

Step 5. Construct the final overlay. The final step in producing a factor overlay is to put the draft manuscript overlay into a final data-base product. You must have support from the cartographic and reproduction elements or sections. See Chapter 8 for the final overlay procedures.