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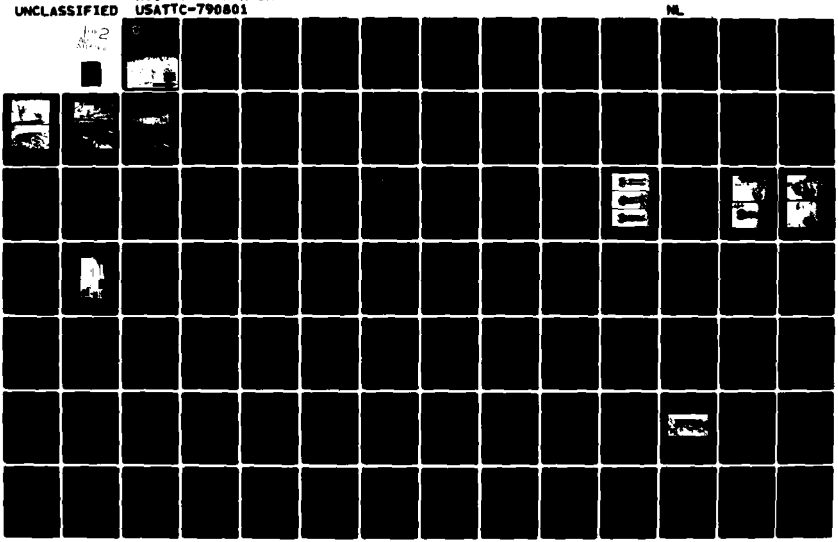

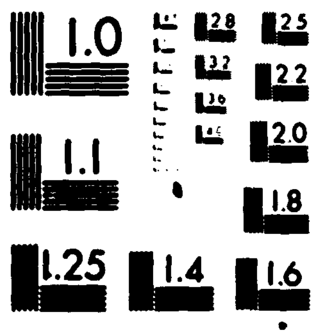

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METHODOLOGY INVESTIGATION

CHARACTERIZATION OF TEST ENVIRONMENT

FINAL REPORT

by

A. A. [illegible]

August [illegible]

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UNITED STATES ARMY TROPIC TEST CENTER

APO MIAMI 34004

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Methodology	Ground Truth Data	Humid Tropics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In October 1979, the Gamboa A-1 area reverts to the Republic [illegible]ma, and a new area has been assigned to USATTC for environmental testing [illegible] report is a pilot program accomplished with limited resources to determine the direction of future studies. The study characterizes the terrain in the new area.

Approximately one-half of the new area cannot be negotiated by foot without difficulty because of steep slopes or soft soil/dense jungle vegetation. Variations in vegetation afford suitable conditions for testing canopy penetration

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and surveillance detection; variations in relief provide adequate conditions for testing communication devices. Areas are very limited for testing munitions penetration and explosives because of proximity to the Panama Canal and Gamboa, and the lack of grasslands.

Recommended actions were to collect additional terrain data to permit a better definition of boundaries of terrain factor maps, obtain new 1:10,000 aerial photographs to assist in refining terrain unit boundaries, and develop a flexibility to test in a variety of areas on an ad hoc basis rather than in a single area.

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FOREWORD

The investigation was conducted by the Gamboa Task Group of the US Army Tropic Test Center (USATTC) during the period May to August 1979. The Task Group consisted of USATTC staff, contract personnel and Student Assistants temporarily employed for this project. Students participating were: Harold J. West, James A. Saffold, Thomas S. Wallace, Ricardo Garcia, Mitchell Pierson, William Roger, Jr., Mary Kelleher, and Marla A. Hinman. The task force was assembled to produce appropriate environmental data necessary to locate, describe, plan, and construct new environmental test facilities within allotted funds. The facilities are required by USATTC to execute its RDTE mission, because the areas on which the present facilities are located will revert to the Republic of Panama in October 1979.

This report includes a synthesis of available environmental data selected to describe the environment of the area in appropriate terms, procedures used to collect and process available ground truth data collected specifically for this investigation, application of data, and procedures used to portray the information on terrain factor maps.

To ensure that the state-of-the-art was used for collecting, analyzing, and portraying the terrain data in terms usable as input to available mathematical models, J. H. Robinson and D. Andrews of the US Army Engineer Waterways Experiment Station and M. Satterwhite and P. Henley of the US Army Engineer Topographic Laboratory participated in the study and preparation of the data base, terrain factor maps, and Appendix C of this report.

Time constraints did not permit completion of the field work or complete analysis of the data, as originally planned; therefore, some data bases and their terrain factor maps lack a good distribution of data to ensure a high level of reliability. Also, some proposed factor maps were not initiated because of lack of data and personnel.

Field work should be continued to expand the present data base and to include in the data base those factors such as soil strength that are seasonal in nature; and the present terrain factor boundaries should be refined as data permit.

The concepts and methodology pursued in achieving the objectives of this study should be continued in the future and the study should be considered a living thing. It provides a sound basis on which research and development can improve methods and techniques for testing, and for evaluating Army materiel in the humid tropics in an orderly and meaningful manner.

SECTION I. SUMMARY

1.1 BACKGROUND

a. After 1 October 1979 most of US Army Tropic Test Center (USATTC) environmental test areas located in the Gamboa A-1 area (figure 1) will revert to the Republic of Panama in accordance with terms of the 1977 Panama Canal Treaty. A new area (Cerro Pelado) has been assigned USATTC for environmental testing and study purposes. Therefore, it was necessary to establish an environmental data base of the new area.

b. Although implementation of the Treaty will limit access to areas suitable for future environmental testing in the humid tropics, the mission of USATTC remains unchanged. As in the past, the final analysis of quality assurance evaluations of many categories of Army materiel can best be achieved with confidence through realistic developmental and operational testing, coupled with mathematical performance prediction models. The process ensures that the specified performance criteria are met in a variety of climatic categories. Thus, for meaningful environmental tests, facilities are required to evaluate known and perceived effects which will influence the performance of man and materiel when tested against mission profiles.

1.2 OBJECTIVES

The primary objective of the investigation was to characterize the terrain in the new area assigned USATTC to conduct environmental materiel tests.

Secondary objectives were to:

a. Establish uniform procedures for equipment care and use, collection, tabulation and portrayal of terrain data (Appendixes B and C).

b. Establish a foundation for a sound terrain data base (Appendix D).

c. Prepare appropriate terrain factor maps using available data, air photo analysis and mapping techniques, and data collected specifically for this study (Appendixes C and E).

1.3 SUMMARY OF PROCEDURES

a. To fulfill the terrain characterization requirements, a literature search was conducted and information pertinent to this study was evaluated and summarized for each terrain factor of interest. Most of the usable data were contained in a previous USATTC methodology investigation (Davis, et al., January 1979) (reference 1) which characterized the terrain in the former Gamboa A-1 area which forms part of the new area. The terrain factors and factor classes used to portray selected terrain factors are similar in many respects.

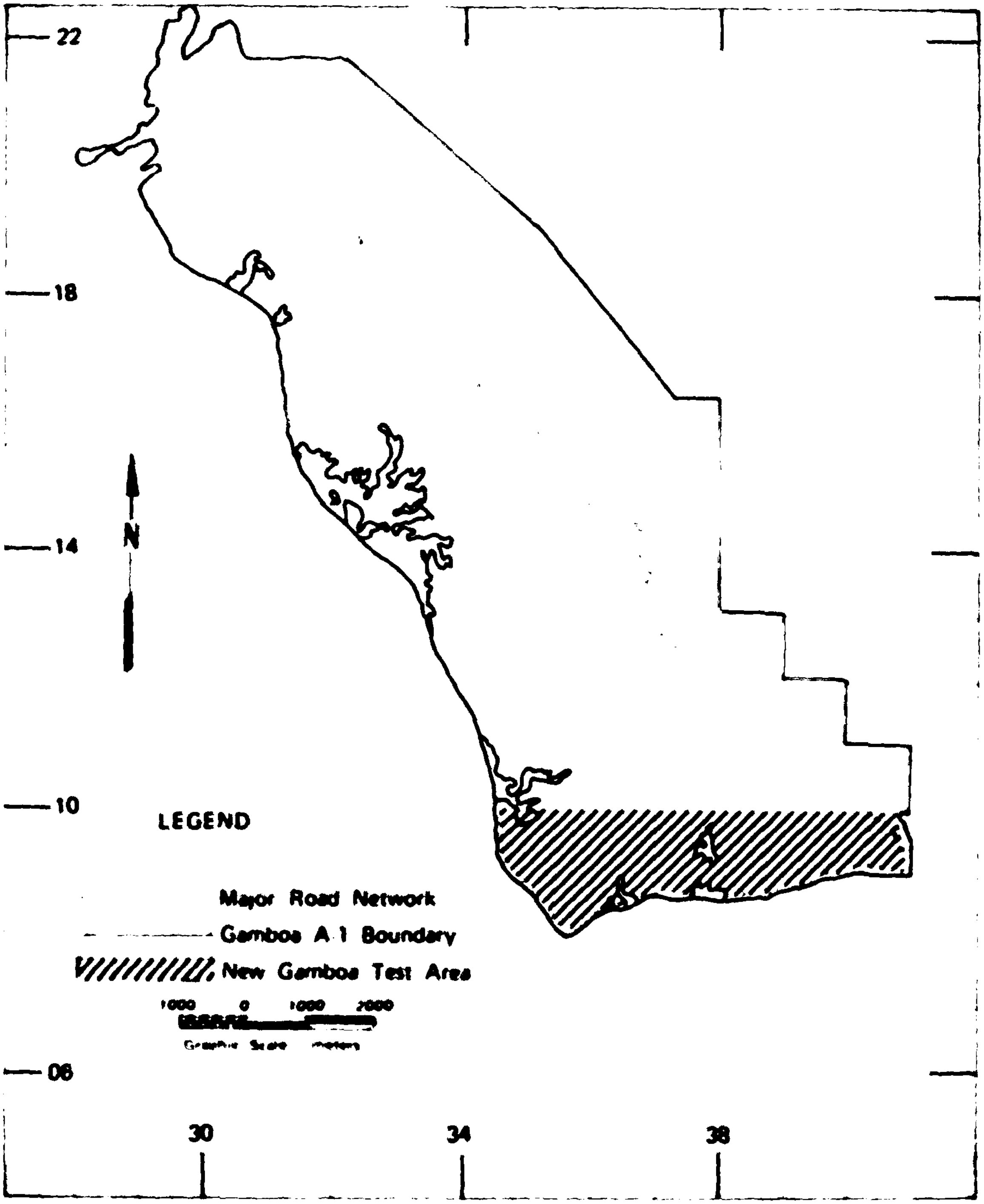

Figure 1. Gamboa Test Areas.

b. After maps such as geology, landform, drainage, slope, and soil types were prepared, these plus aerial photographs were used to select sampling sites that would provide a range of data for terrain factors for which maps would be prepared at a scale of 1:10,000. For example, soil types, geology and slope maps were used to locate sites in each soil type and at high, medium, and low topographic positions because topographic position contributes to soil wetness which in turn affects soil strength. Panchromatic and infrared aerial photography at scales of 1:10,000 and 1:20,000 were used to select vegetation sampling sites on the basis of tone and texture patterns. The final selection of sample sites was made by the survey team chief who determined if the sampling sites met the site selection criterion.

c. At each site, data were recorded to locate and adequately describe the surface composition, surface geometry and vegetation characteristics. The procedures used to collect, tabulate, and process the data are given in Appendix B. An example of the specific data collected is found in table B-1.

d. The total terrain data base, including maps and aerial photographs, was used to establish mapping units. The techniques used to establish and portray mapping units for several factor maps are discussed in Appendix C.

1.4 SUMMARY OF RESULTS

a. Maps at a scale of 1:10,000 delineating areas of designated terrain factor class values or descriptions were prepared for all terrain attributes listed below:

General

(1) Topography
(2) Landform
(3) Geology
(4) Surface Drainage

Soil Type

(5) USDA
(6) USCS

Soil Strength

(7) Cone Index, 0- to 6-inch depth
(8) Cone Index, 6- to 12-inch depth
(9) Rating Cone Index, 0- to 6-inch depth
(10) Rating cone Index, 6- to 12-inch depth
(11) Slope

Vegetation

(12) Tropic Forest Life Zone
(13) Physiognomic
(14) Stem Density

NOTE: The Terrain Factor Maps at Appendix E are not a part of this report but can be requested from USATTC by authorized agencies.

b. Uniform procedures were established for collecting, tabulating, and portraying terrain data.

c. A sound terrain data base was initiated and terrain factor and factor class values were arranged in such a manner that they can be used as input to mathemetical models simulating materiel performance.

d. The data for the terrain factors listed above were mapped at a scale of 1:10,000 (Appendix D). The factor classes and ranges used to map each factor are shown on the maps. For those terrain factors that were mapped with some confidence, the area occupied and the frequency of occurrence of each factor class mapped were determined.

1.5 CONCLUSIONS

a. The factor maps and the data base assembled for this study provide the RDTE community with a ready update of available terrain information for the new USATTC environmental test area.

b. Statistics derived from the data base, such as areal occupancy and frequency of occurrence of terrain factor classes, are useful in establishing limits of realistic conditions against which materiel performance can be tested.

c. Individual factor maps can be used to select, with greater confidence, test areas in which a cause-effect relation may exist among the soldier, test item and terrain characteristics.

d. Approximately one-half of the new area cannot be negotiated by foot without difficulty because of steep slopes or soft soil/dense tangled vegetation conditions. Vegetation characteristics such as density, stem size, stem spacing and canopy cover do not afford a wide enough range in characteristics for good testing of canopy penetration and surveillance detection. The variation in relief and elevation should provide adequate conditions for conducting tests with communications equipment. Although variation in soil type is small, a range in seasonal soil strength occurs for testing penetrations of munitions and other devices providing the vegetation is part of the testing requirement. Proximity of the test area to the Panama Canal and Gamboa, and the lack of grasslands limits the area's use in testing munitions penetration and explosives.

1.6 RECOMMENDATIONS

a. This study should be extended to permit collection of additional terrain data for a better definition of boundaries of terrain factor maps and test courses.

b. New 1:10,000 panchromatic and infrared aerial photography should be obtained for photo analysis purposes and refinement of map units.

c. Data in this report should be used for background information for future revisions of Test Operations Procedures 1-1-154, Ground-to-Ground Target Detection in Tropic Forests; 1-3-550, Man-Pack Portability Testing in the Tropics; and other TOPs considered appropriate.

SECTION 2. DETAILS OF INVESTIGATION

2.1 DESCRIPTION OF NEW GAMBOA TEST AREA

a. The location of the new and former Gamboa test areas is shown in figure 1, above. The original Gamboa test area occupied about 18,000 acres (7,450 hectares) whereas the new area occupies about 3,500 acres (1,450 hectares). When the area occupied by the 1,000-foot (307 m) perimeter right-of-way is subtracted, about 2,500 acres (1,035 hectares) are available as a test area. It is understood that the perimeter area is available for testing on an ad hoc basis.

b. The area is located near the town of Gamboa. It is bounded by the Rio Chagres on the east, the Panama Canal Railroad on the south and west, and by the 10-grid-line on the north. An aerial oblique of sections of the area is shown in figure 2. Photographs of the terrain data sites are shown in Appendix F.

c. Most of the area west of the Cerro Pelado Military Reservation (CPMR) has been mapped geologically as a bouldery conglomerate composed of sand, silt, and boulder mixture. This formation is characterized by a dendritic drainage pattern with hills of low to intermediate relief. Intrusive igneous rocks occur along the western part of the area in which are formed steep-sided ridges. Just west of CPMR is a fairly large area of flat-lying sedimentary rocks which have formed rolling hills. The area north and east of CPMR contains tilted tuffaceous sandstone which exhibits angular to trellis drainage patterns, and high hills with sharp crests and steep sloping drainageways. The eastern part of the area contains undifferentiated igneous rock forming steep, sloping, rounded hills and drainageways. Natural and manmade alluvium occurs along the eastern, southern and western boundaries. A large alluvial area is located in the northwestern part of the area.

d. The predominate landform in the area is composed of hills with local relief from 100 feet (30 m) to 300 feet (92 m). The hills have sharp crests and steep slopes—40 to 70 percent slopes are not uncommon. The orientation of the hills is usually in a north-south direction except east of CPMR where the orientation is generally east to west. The highest hills occur near CPMR where the elevation is approximately 600 feet (185 m). Hill-line spacings vary from 0.1 miles (160 m) to 0.5 miles (810 m). Bottomland flats occur along the perimeter of the area. Marshes occur along the eastern and western boundaries and hydraulic fill areas along the southern boundary adjacent to the Canal.

e. The streams all drain into the Panama Canal or into the numerous lakes which occupy about 6 percent of the area. The drainage pattern is primarily dendritic but some angular to trellis patterns are found. Most of the drainageways have very steep-sided slopes and present a significant barrier to movement. The streams are spaced from about 0.1 mile (160 m) to 0.5 miles (810 m) apart. The orientation of the stream is rather random.

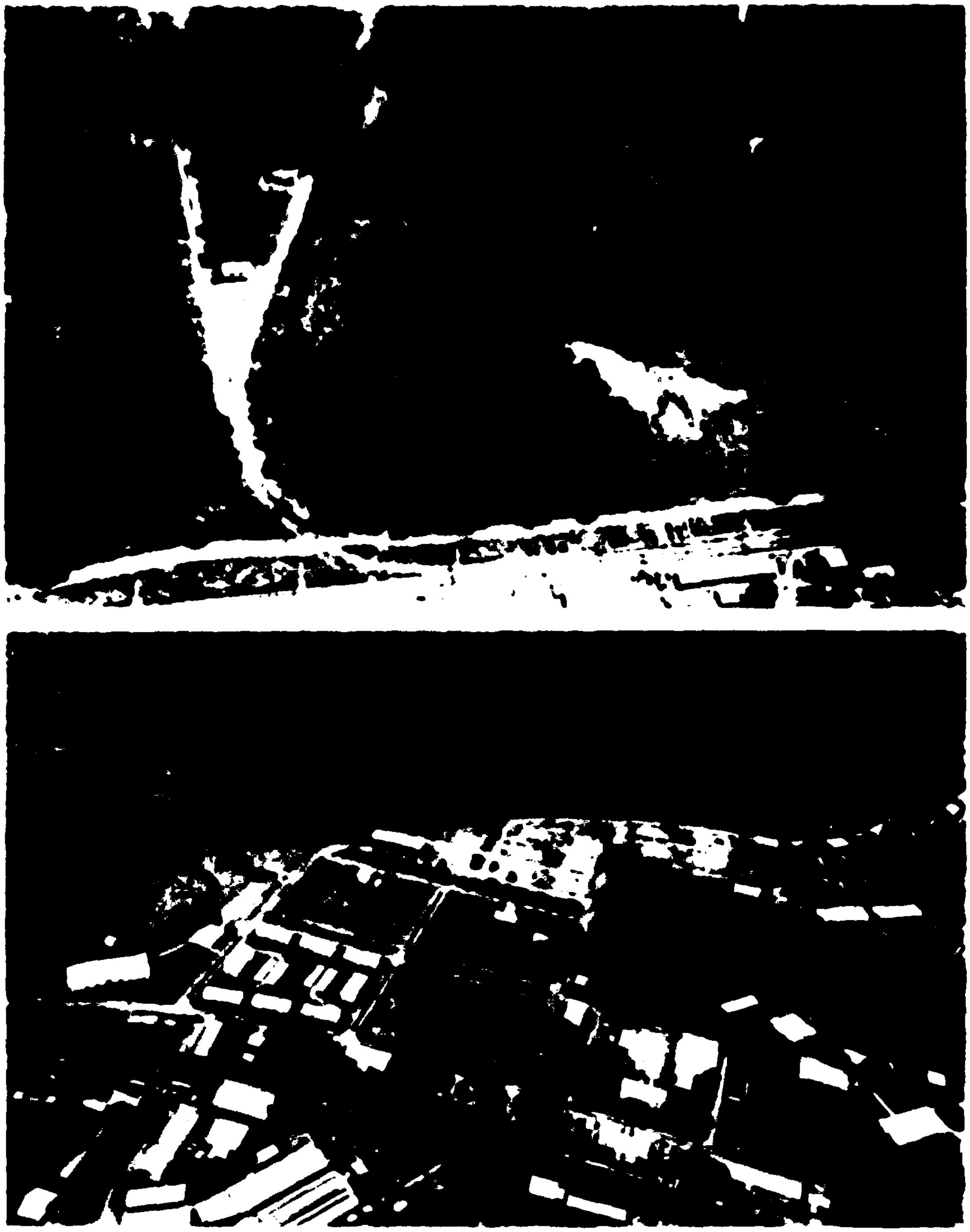

Figure 2. Eastern Section of Test Area.

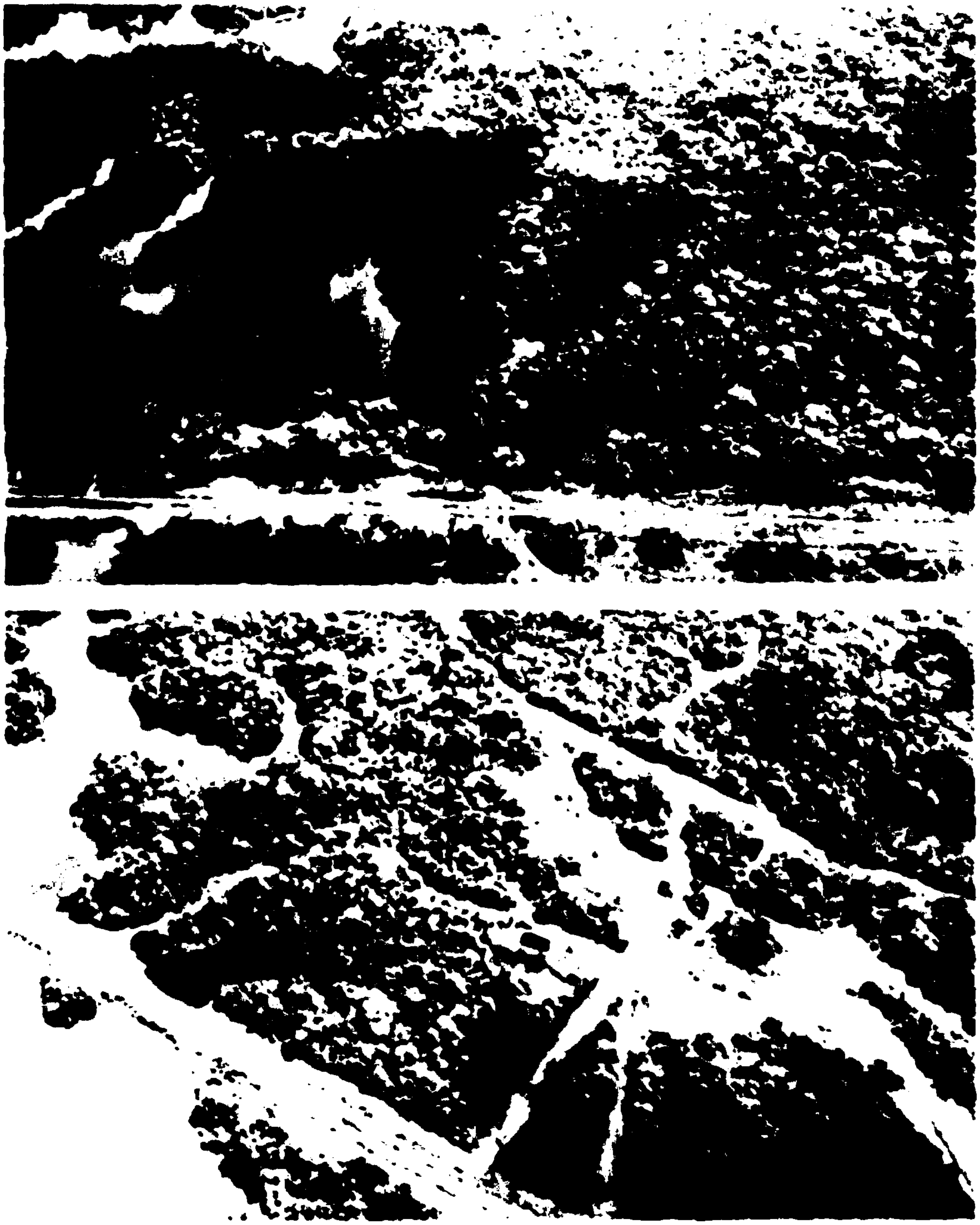

Figure 3. Central Section of Test Area.

Figure 4. Western Section of Test Area.

f. Although various parent materials are found in the area, the weathering processes have formed fine-grained soils with the clay fraction being dominate over the silt and sand. The USDA soil types are primarily Arraijan clay with some patches of Santa Rosa clay and Paraiso clay. Wet, highly organic soils are found in the marshes. According to the Unified Soil Classification System (USCS) the upland residual soils are silty clay (MH) and silty clay and fat clay mixture (MH-CH). Like USDA soil types, organic soil (OH) occurs in the marshes.

g. In the topographic positions that afford good surface drainage, the cone index of the surface to 6-inch layer ranges from about 60 to greater than 300. The cone index usually increases in strength with depth. Although the soils are reasonably firm in the wet season, they are slippery when the surface is wet because of their silt and clay content. The cone index in the wet marshes is 10 or less.

h. The topography of the area is highly variable because of the randomness of the hills and the variations in relief. Flat or bottomlands occupy 12.8 percent of the area, slopes of 2 to 20 percent occupy 32.2 percent, slopes of 20 to 60 percent occupy 37.2 percent, and slopes greater than 40 percent and water bodies occupy 17.8 percent of the area.

i. The vegetation according to the Holdridge Life Zone Classification System is Tropical Moist Forest. Accordingly, the vegetation in the western section is predominately secondary association of disturbed vegetation 5 to 15 years old, but islands of vegetation less and greater than 5 to 15 years old also are found in the area. Several fairly large patches of tall grasses occur in the western section. East of Lake Calamito and extending to CPMR the vegetation is similar to the vegetation described above except that it is more mature; several islands of grassland also occur. East of CPMR tall multistratal mature forests are found. Mangroves and grass marshes are located along the Rio Chagres. The physiognomic or shape and form characteristics of the vegetation on the test area have been described as mostly mature or semimature forest stands; except in areas where the soil is turned or recent burning occurred, producing a secondary life tree growth. Tree height ranges from 50 to 150 feet (15 to 45 m). Cane-like semiwoody stemmed grass species are common in the open areas along the Panama Canal Railroad and Pipeline Road where periodic cutting and burning have maintained the grasslands. Grasslands are also found on semiupland areas that have been cleared of the tree cover and are used for siting canal navigation markers or communication towers. Grass or tangle areas occupy the low marshlands.

j. The climate in the environmental test area is humid tropic. The climate is described in detail for the dry and wet season for the basic weather parameters. Mean wet and mean dry season rainfall are given in figures 5 and 6.

Parameter	Dry Season a/	Wet Season b/
Temperature -°F (°C)		
Open temperature - daytime	82-89 (28-32)	80-86 (27-30)
Open temperature - nighttime and during heavy rain	65-70 (18-21)	70-73 (21-23)
Highest temperature ever measured	95 (35)	95 (35)
Lowest temperature ever measured	60 (16)	68 (20)
Jungle temperature - daytime	78-81 (26-27)	79-82 (26-28)
Jungle temperature - nighttime	74 (23)	74 (23)
Dew Point - all day	70 (21)	73 (23)
Relative humidity - percent		
Average lowest daily c/	56	71
Duration of sunshine - hrs		
Daily average	8.2	4.5
Global radiation -		
langleys (Joule/meter^2)	435	315
Horizontal plane - daily average	(1820.04×10^4)	(1317.96×10^4)
Direct solar radiation -		
langleys (Joule/meter^2)	275	130
Horizontal plane - daily average	(1150.60×10^4)	(543.92×10^4)
Indirect solar radiation -		
Langleys (Joule/meter^2)	160	185
Sky radiation on horizontal plane - daily average	(669.44×10^4)	(774.04×10^4)
Prevailing wind direction	N	NNW
Mean wind speed - mph (kph)		
Noon	6 (10)	5 (8)
Night	0 (0)	0 (0)
Rainfall - inches (cm)		
1-hour maximum	2.5 (6.4)	3.5 (8.9)
24-hour maximum	8.4 (21.3)	17.0 (43.2)
Monthly maximum	12.0 (30.5)	37.0 (94.0)
Monthly average	1.0 (2.5)	9-12 (22.9-30.5)
Yearly average	105 (267)	

a/ Data apply to February and March-the driest months.
b/ Data apply to June through November.
c/ Maximum relative humidity of 95 to 100 percent is reached nightly for several hours.

2.2 DATA COLLECTION

a. Thirty-one data sites were sampled. At each site complete surface composition, surface geometry, and vegetation data were collected, as required, as input to various mathematical models for predicting performance of various items of Army materiel.

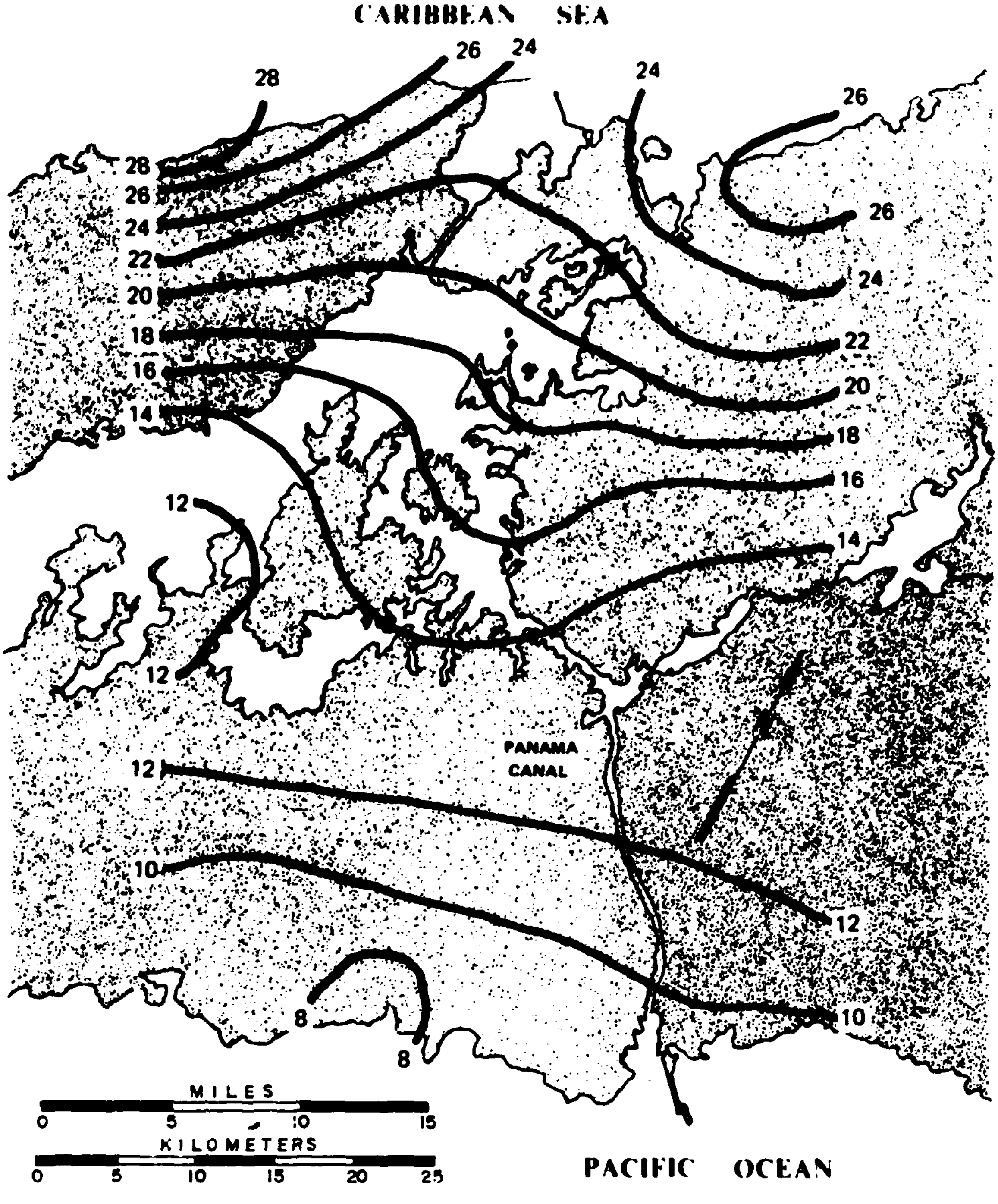

Figure 5. Mean Wet Season (November) Rainfall (Inches).

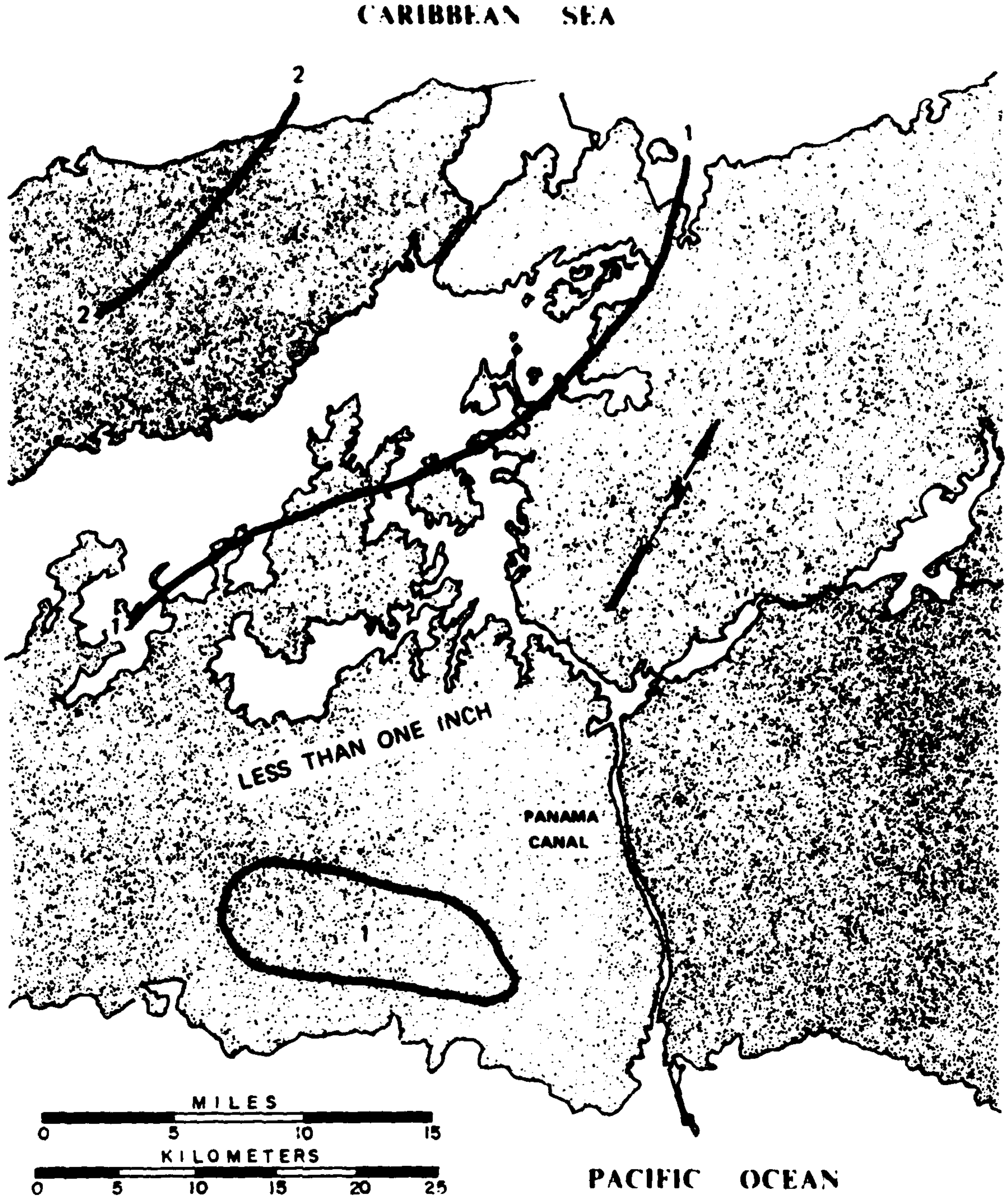

Figure 6. Mean Dry Season (March) Rainfall (Inches).

b. The data collected for this study are summarized in Appendix D. The tables contain the following data:

D-1 Summary of Site Description Data.
D-2 Summary of Surface Composition Data.
D-3 Summary of Surface Geometry Data.
D-4 Summary of Vegetation Data--Structural Cell Method.
D-5 Summary of Vegetation Data--Modified Quarter Method.

c. The procedures used to select the data sites, and detailed procedures for collecting, tabulating, and summarizing the terrain data are given in Appendix B. Some of the data collected are portrayed in Appendix E as terrain factor maps at a scale of 1:10,000.

d. The equipment used to collect terrain data operated effectively in the local climate, except for the Hvorslev Sampler used to obtain moisture content/density and remolding samples. Apparently, the adhesion of the soil entering the sampler tube is greater than the shear strength of the soil requiring a sample tube penetration of about 6 inches to obtain a 3-inch-long sample. For this reason, the data shown in Appendix D contain few density and remolding index measurements.

2.3 PREPARATION OF TERRAIN FACTOR MAPS

a. Conventional air photo interpretation methods and techniques, supplemented with existing maps and specific terrain data measurements, were used in the preparation of areal terrain factor maps. The technique consisted of preparing an aerial mosaic at a scale of 1:20,000, using February 1973 panchromatic photography. Color infrared aerial photography was also used to map vegetation characteristics in the eastern half of the area. To expedite the transfer of terrain factor class boundaries to base maps, the scale of the photos was reduced to 1:10,000.

b. Boundaries were drawn around areas that exhibited patterns identifiable according to tone, texture and geometry. Because the area being mapped was primarily forested, all of the patterns identified primarily reflected differences in vegetation characteristics. After the various patterns were identified, the association of vegetation type, topographic position, surface drainage, soil type, geology, climate, and landform to available quantitative terrain data (Davis, et al.) was established where possible.

c. Where old or new ground truth data occurred within a pattern, a number for the class factor range was assigned, as well as for similar patterns that occurred on the mosaic. The factor class intervals used to describe terrain for ground mobility purposes were used for slope, soil type and soil strength. Vegetation and surface geometry class ranges required could not be obtained with air photo interpretation techniques; therefore, a compromise was reached to face the reality of producing some useful data. Vegetation factor maps were prepared using the life zone and physiognomic descriptors. Obstacle and microgeometry characteristics could not be inferred to the degree of detail required from the mapping techniques used; therefore, no factor maps were prepared.

d. Techniques and information used to prepare factor maps varied as indicated below.

Terrain Factor	Available Maps	Available Ground Truth	Air Photos	New Ground Truth
General				
Topography	X			
Landform	X		X	X
Geology	X		X	X
Surface Drainage	X		X	X
Soil Type				
USDA	X		X	X
USCS	X		X	X
Soil Strength				
Cone Index, 0-6 in. depth	X	X	X	X
Cone Index, 6-12 in. depth	X	X	X	X
Rating Cone Index, 0-6 in. depth	X	X	X	X
Rating Cone Index, 6-12 in. depth	X	X	X	X
Microgeometry				
Slope	X			
Vegetation				
Tropic Forest Life Zone	X		X	X
Physiognomic			X	X
Stem Density	X	X	X	X

In addition to the above techniques, information such as soil moisture-strength prediction relations developed by McDaniel* for Panama Canal Zone soils was used to obtain estimates of soil strength.

e. Once a terrain factor was mapped on the 1:10,000 aerial photographs, the boundaries were transferred to a base map (Appendix E). Where the boundaries were reasonably accurate, the factor classes mapped were measured to obtain information on the areal occupancy and frequency of occurrence of each factor class mapped.

2.4 APPLICATION OF TERRAIN FACTOR INFORMATION

a. A terrain factor map portrays the distribution of factor classes which have been assigned class ranges according to the effect they may have on the performance of a number of military activities. These maps have a variety of uses.

b. Once an activity is known, along with the terrain factors that influence its performance, the appropriate factors can be combined to produce a terrain factor complex map, if convenient, or each factor can be analyzed independently. If a mathematical model or a nomograph is available to predict performance, the terrain data can be obtained from the factor maps.

c. Statistics such as areal occupancy and frequency of occurrence of terrain factors are most useful in selecting test areas or courses to ensure that the item will be tested in a realistic and representative environment. On the basis of single factors, the areas can be delineated in which item performance will be zero or areas in which it can be expected to have no effect on activity performance. The remaining areas would then be considered, along with other limiting terrain and logistical factors, for testing.

d. Relations among soil conditions and vehicle characteristics, and traction and slope performance, are illustrated in figure 7. If it is known that ground-crawling vehicles cannot negotiate slopes greater than about 55 percent because of power stall, and cannot travel on a soil strength having a rating cone index of 25 or less, nor negotiate wet, fine-grained soil slopes greater than 8 percent, then the slope, soil type and rating cone index factor maps are used to identify go, no-go areas. Likewise, if a level, grass area containing deep, fine-grained soils in a well-drained topographic position is required for explosive testing, then soil type, physiognomic vegetation and slope maps are consulted to identify the areas that meet the desired terrain specifications.

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* McDaniel, A.R., Misc. Paper No. 4-355, Trafficability Predictions in Tropical Soils, Report 3, Panama Study No. 2 (Oct 1961-Sept 1963), US Army Engineer Waterways Experiment Station, Vicksburg, Miss., August 1966.

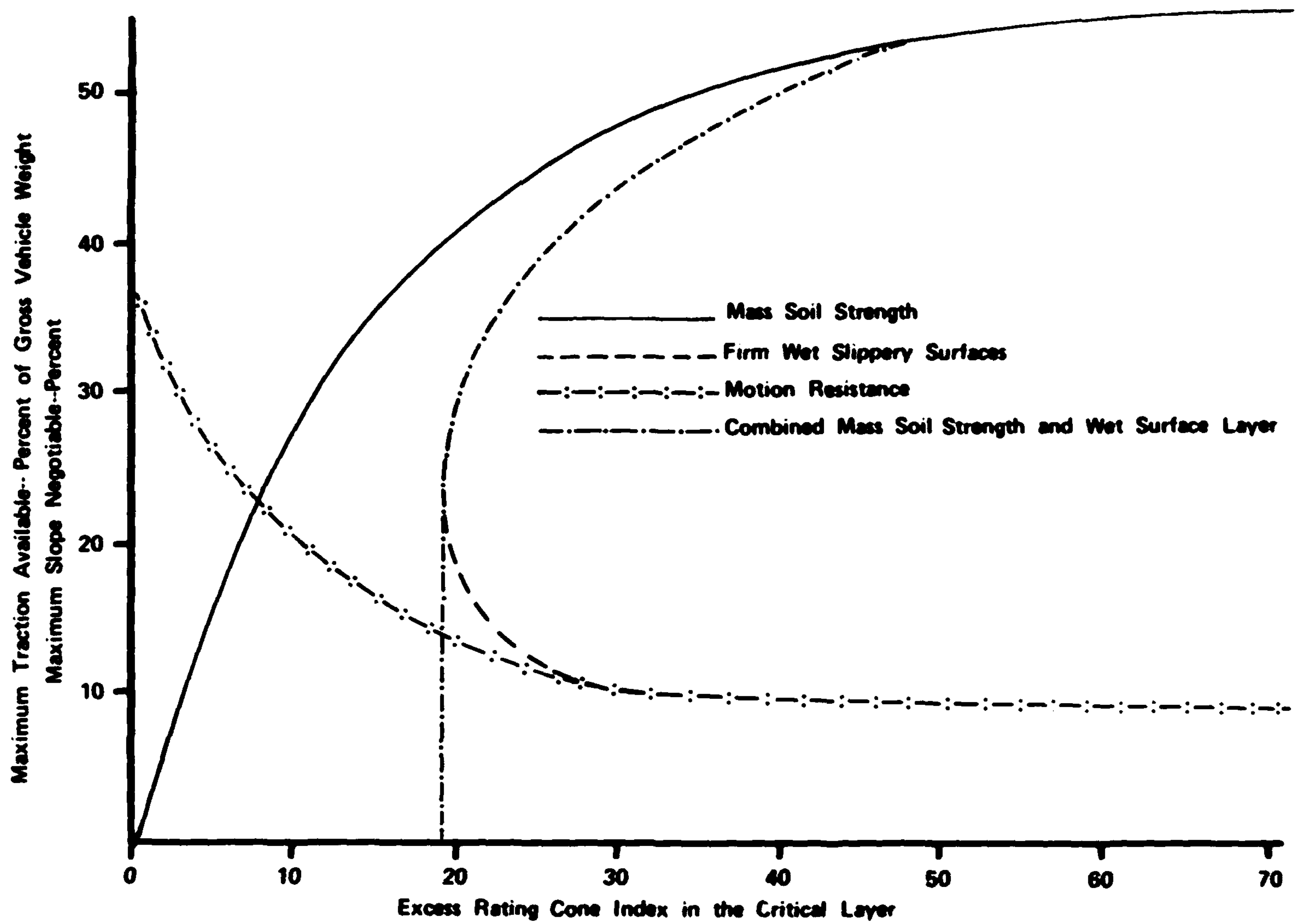

Figure 7. Performance of Wheeled Vehicles on Fine-Grained Soil Surfaces.

e. The statistics derived from the slope factor map are shown below.

Slope Class	Class Range percent	Areal Occupancy acres	Areal Occupancy percent	Occurrence numbers	Occurrence frequency
1	0 - 2	451	12.8	11	2.8
2	2.1 - 5	95	2.7	5	1.3
3	5.1 - 10	260	7.4	31	7.9
4	10.1 - 20	778	22.1	117	29.8
5	20.1 - 40	823	23.4	81	20.7
6	40.1 - 60	846	13.8	62	15.8
7	60.1 - 70	218	6.2	37	9.4
8	>70	208	5.9	27	6.9
Water		201	5.7	21	5.4
		3,520	100.0	392	100.0

This tabulation shows that slopes greater than 60 percent occur in 12.1 percent of the area, and that there are 64 patches of slope classes 7 and 8 with a frequency of occurrence of 16.3 percent. From the above information it can be deduced that slope alone will deny vehicle passage over 12.1 percent of the area. Other factors such as soil condition and vegetation combined with slope will also deny passage of additional areas.

SECTION 3. APPENDIXES

APPENDIX A. METHODOLOGY INVEST' ATION DIRECTIVE AND PROPOSAL

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DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005

DRSTE-AD-M 20 April 1979

SUBJECT: Directive, Characterization of Test Environment, TRMS No. 7-CO-RD9-TT1-004

Commander
US Army Tropic Test Center
ATTN: STETC-TD-O
APO Miami 34004

1. Reference is made to TECOM Regulation 70-12, dated 1 June 1973.

2. This letter and attached STE Forms 1188 and 1189 (Incl 1) constitute a directive for the subject investigation under the TECOM Methodology Improvement Program 1T665702D625.

3. The information at Inclosure 2 and the attached guidance at Inclosure 3 are the bases for headquarters approval of the subject investigation.

4. Special Instructions:

a. All reporting will be in consonance with paragraph 9 of the reference. The final report, when applicable, will be submitted to this headquarters, ATTN: DRSTE-AD-M, in consonance with Test Event 52, STE Form 1189.

b. Recommendations of new TOPs or revisions to existing TOPs will be included as part of the recommendation section of the final report. Final decision on the scope of the TOP effort will be made by this headquarters as part of the report approval process.

c. The utilization of the funds provided to support the final investigation is governed by the rules of incremental funding.

d. The addressee will determine whether any classified information is involved and will assure that proper security measures are taken when appropriate.

e. Upon receipt of this directive, test milestone schedules will be immediately reviewed in light of known other workload and projected available resources, in accordance with provisions of paragraph 2-4 to TECOM Regulation 70-8. If rescheduling is necessary, this headquarters, ATTN: DRSTE-TO-O, will be notified by 1st Indorsement not later than 4 May 1979. If schedules can be met, a P8 entry will be made directly into TRMS master file by that date.

f. The Methodology Division point of contact is Mr. Roger L. Williamson, ATTN: DRSTE-AD-M, AUTOVON 283-2170/2375.

FOR THE COMMANDER:

/s/SIDNEY WISE
/t/SIDNEY WISE
C, Meth Imprv Div
Analysis Directorate

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as

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March 1979

1. TITLE. Characterization of Test Environment

2. CATEGORY. Environmental Testing

3. INSTALLATION. US Army Tropic Test Center
P. O. Drawer 942
APO Miami 34004

4. PRINCIPAL INVESTIGATOR. To Be Designated
Materiel Test Division
STETC-TD
AUTOVON 313-285-5412

5. STATEMENT OF THE PROBLEM. A quantitative terrain factor mapping study of a new environmental test area (Cerro Pelado), using standardized methods and techniques, is required to characterize selected terrain features (slope, soil type, soil strength, vegetation, visibility, surface microgeometry, etc.) from which a terrain factor complex map will be prepared. A terrain factor data base is required to establish realistic standard reference test courses such as man-pack portability and input to computerized soldier/item/activity models.

6. BACKGROUND. As a result of the implementation of the Panama Canal Treaty it is necessary to relocate USATTC's environmental test area and associated testing facilities and test courses. In order to establish meaningful test courses on the new area, information is required about the basic terrain features that have an effect on activities and materiel to be tested in a human tropic environment.

7. GOAL. The investigation will develop terrain factor maps of newly selected test area. Standardized methods and techniques will be used so that meaningful comparisons can be made.

8. DESCRIPTION.

a. Terrain data bases will be prepared using terrain factor mapping standardized methods and techniques developed by the US Army Corps of Engineers. Areal and linear terrain factor complex maps will be prepared. The linear terrain factor complex maps will include roads, trails, and drainage features. The areal terrain maps will include all other areas. The test course data base will include mobility traverses in cross-country travel, roads, and trails, man-pack portability, etc. Availability of this data base will allow for adaptation of available terrain-item performance models such as the Army Mobility Model (AMM), communications, scatterable mines, engineer equipment, river-crossing equipment, sensors, etc.

b. Once tropic terrain data bases are prepared for use as input to computerized soldier/item/activity models, meaningful studies can be conducted. For instance, the areas occupied and the frequency of occurence of terrain units mapped in the test area can be determined. From scenarios of given military posture (defense, offense, retrograde) mission profiles can be established of selected activities and the effectiveness of these activities can be determined by applying appropriate performance/activity models. The information can also be used to establish realistic and more meaningful standard reference test courses.

c. The output from validated performance models can be used as a guide in designing meaningful tests and in evaluating the results. For example AMM can be employed to determine where the XM1 Tank or any other vehicle could go or not go, as well as identify speed if able to traverse. The AMM also identifies the reason a vehicle cannot negotiate a specific terrain unit. Changes in vehicle characteristics can be introduced to determine the degree of improvement in performance achieved, if any. The vehicle performance predictions can be used as a guide to select meaningful test sites.

d. Single factor data, such as soil type and strength, can be used to predict the performance of engineer equipment, scatterable mine soil penetration, etc. Activity performance comparisons can also be made for the various areas for which terrain and equipment/item data are available. All of the above plus many other activity studies can be obtained very inexpensively, because large sums of R&D dollars have already been spent by DARCOM, TRADOC and OCE on developing and refining engineering performance models and data bases to feed them.

e. Investigation plan outline.

1st Qtr Initiate interagency contract or agreement
2nd Qtr Prepare terrain factor maps using available data
3rd Qtr Collect and analyze terrain factor data
4th Qtr Prepare final report

f. This investigation will develop terrain factor maps of a selected Canal Zone area.

9. PROGRESS. This is a new investigation.

10. JUSTIFICATION.

a. The investigation will provide terrain factor maps using standardized techniques of a selected Canal Zone area. With this information it will be possible to establish realistic standard reference test courses and mission profiles for testing and evaluating materiel in the humid tropics. TECOM's tropic environmental testing capability would be greatly enhanced and would place TTC at the state-of-the-art.

b. Dollar Savings. Improved soldier/item/activity testing would result in mission effectiveness and dollar savings, but are impossible to estimate at this point.

c. Current and likely future tests which would benefit from this effort are shown in the following schedule:

	FISCAL YEAR			
	80	81	82	83
Roland II		PQG		
Mortar Locating Radar TPQ-36		PQG		
Artillery Locating Radar TPQ-37		PVG		
High & Mod Persis Obscurants				PQG
Remotely Monitored Sensor System		PQG		
XM1 Main Battle Tank		PQG		

d. Recommended TRMS Priority: 01.

e. Association with Requirements Documents: N/A

11. RESOURCES.

a. Financial.

(1) Funding Breakdown

Dollars (Thousands)

	FY79	FY80
Personnel Compensation		
Travel	2	
Contractual Support	17	20
Consultant and Other Services	5	5
Materials and Supplies	4	
Equipment	2	
	30	25

(2) Explanation of Cost Categories:

Contract Support. USATTC contract personnel will be used for field data collection and processing.

Consultant and other Services. Available mapping services will be obtained from organizations such as Waterways Experiment Station or Engineer Topographic Laboratory.

b. Anticipated Delays. None.

c. Obligation Plan

Obligation Rate:	FY Qtr	1	2	3	4	Total
			FY79			
				10	20	30

d. In-House Personnel

	Man-Hours Number	Required	Study Hours Available
Physical Science Admin, GS-0801	1	80	80
Gen Engr, GS-0801	1	200	200
Engr Tech, GS-0802	1	300	300
Soils Spec, MOS 51G20	1	300	300
		880	880

12. INVESTIGATION SCHEDULE.

	FY79 M	J	J	A	S	FY80 O	N	D	J	F	M	A	M	J	J
In-House	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Contract	-	-	-	-	-	-	-	-	-	-	-	-	-		
Consultant	-	-	-	-							-	-	-		

13. ASSOCIATION WITH TOP PROGRAM. N/A.

/s/WENDELL L. PRINCE
/t/WENDELL L. PRINCE
Colonel, Armor
Commanding

(END COPY)

APPENDIX B. AREAL TERRAIN MEASUREMENTS AND DATA PROCESSING PROCEDURES

I. INTRODUCTION

A. OBJECTIVE AND SCOPE

The objective of this document is to establish uniform procedures for equipment care and use, collecting, tabulating, summarizing and portraying topographic, soil, obstacle and vegetation data required as input to mathematical models which are used to predict or evaluate the performance of man and materiel performing specified tasks or missions in the humid tropics.

An example of a completed field data form for collecting terrain data is given in Annex I. The data forms include site description information, as well as specific data required to describe and classify selected terrain factors in appropriate terms.

B. LOCATION AND SELECTION OF SITES

Sites are located to provide data on a range of terrain conditions representative of the humid tropics in the vicinity of Gamboa, Republic of Panama. Sample sites will be located on the basis of landform components, such as bottomland and upland flats, lower and middle slopes and so on. These will be selected on a topographic map, with aerial photographs and other mapping information used to insure homogeneity in vegetation cover, soil type and slope. The site will be located near the center of the landform component. In areas covered with trees or obstacles, the landform component to be sampled should be large enough to locate a circular sampling area of approximately 100 feet in diameter. Accessibility is also an important consideration in site location.

C. SAMPLING OF SITE

Each landform component should be sampled several times in the wet season and dry season to establish the range in seasonal variation and the average seasonal values for such terrain factors as soil strength which is largely dependent upon soil moisture content.

II. EQUIPMENT

A. CONE PENETROMETER (0.5-sq-in Cone)

Description

The cone penetrometer (figure B-1) consists of a 30-degree right circular cone of 0.5-square-inch (3.2-sq-cm) base area mounted on one end of a 36-inch (91.4-cm) staff, and a proving ring with dial gage and a handle mounted on the opposite end. The diameter of the staff is 5/8 inch (1.6 cm). The cone is forced manually into the ground and in so doing the proving ring is deflected in proportion to the force applied. A load of 150 pounds (68.0 kg) deflects the proving ring approximately 0.1 inch (0.025 cm) to give a cone index reading of 300. The cone index is considered an index of the shearing resistance of the soil.

Figure B-1. Cone Penetrometer with 0.5-square-inch Cone.

Use

The penetrometer should be checked before use to insure that all nuts, bolts, and joints are tight. The instrument must also be zeroed. To zero the penetrometer, it is held by the handle and allowed to hang vertically. In this position, the dial face is rotated until "0" on the face lies under the needle. If the cone is then allowed to bear on a surface and the instrument is balanced in a vertical position using the fingertips, the dial will be found to read approximately 5 (2 1/2 lb or 1.13 kg), which represents the gross weight of the penetrometer. Penetrometer readings are, therefore, absolute readings which include the weight of the instrument. In use, the tip of the cone is placed on the ground surface where the readings are to be taken. Next, the palm of one hand is placed directly over the handle and the other palm is placed over the back of the first hand. The instrument is then forced into the soil at a slow, constant rate. The desired rate is 6 feet-per-minute (1.8 m) or 12 inches (30.5 cm) in 10 seconds. Readings are taken as the base of the cone enters the ground (surface cone index), and at depths of 3, 6, 9, 12, 15, and 18 inches, unless the capacity of the instrument (cone index 300) is reached at a lesser depth. If the soil strength exceeds the capacity of the penetrometer at a prescribed depth, 300^{+} is recorded for that depth and all remaining depths.

Reading

The penetrometer staff is divided into 1-inch (2.5-cm) increments for the first 6 inches (15.2 cm) and then into 3-inch (7.6-cm) increments to 18 inches (45.7 cm). To read the cone index at the proper depth, focus the eyes on the ground surface next to the staff, and as the staff penetrates the depth at which the reading is prescribed, focus the eyes on the dial and read the value indicated by the dial hand. This process is repeated for each depth until a set of readings is completed. The readings called out by the instrument reader are written by the recorder on the proper form. The penetrometer is withdrawn from the soil by grasping the staff and pulling upward.

Adjustment and Care

The penetrometer needs little adjustment or care beyond keeping it clean and free of rust, keeping all parts tight, and frequently checking the zero of the instrument. The penetrometer should be cleaned thoroughly each day after use, with particular care taken to see that no grit is caught between the extensometer arm of the dial gage and the bottom bearing block. If either or both pairs of bearing blocks should be loosened and moved, they must be adjusted to lie on a diameter of the ring and then retighened.

B. CONE PENETROMETER (0.2-sq-in Cone)

Description

This cone penetrometer is similar to the penetrometer with a 0.5-square-inch cone except that the cone base is 0.2 square inch (1.3 sq cm) in area and is mounted on a staff 18 inches (45.7 cm) long and 3/8 inch (0.95 cm) in diameter. A 150-pound load on the 0.2-square-inch cone corresponds to a cone index of 750. If the 0.2-square-inch cone is used with a 300 maximum dial face, the readings are multiplied by 2.5 (2.5 x 300 = 750) to obtain the correct cone index.

Use

This instrument is substituted for the penetrometer with 0.5-square-inch cone measuring the strength of the soil whenever cone index measurements greater than 300 are obtained. If the soil strength exceeds the capacity of the instrument with 0.2-square-inch cone at a prescribed depth, 750^+ is recorded for that depth and all remaining depths.

Adjustment and Care

Instructions for the adjustment and the care of this instrument are the same as those indicated for the penetrometer with the 0.5-square-inch cone.

C. HVORSLEV SOIL SAMPLER

Description

The Hvorslev soil sampler is designed for taking undisturbed (or only slightly disturbed) samples from comparatively soft soil. It may be used satisfactorily on nearly all cohesive soils when the cone indexes range from about 5 to about 150, except those containing gravel or other root obstructions. The lower limit is reached when the soil becomes soft enough to flow out to the cylinder. The upper limit is determined by the operator's ability to force the cylinder into the soil with a smooth, continuous motion.

The Piston

The primary purpose of the piston is to maintain a partial vacuum above the sample and thus prevent its compression as the cylinder is forced into the soil. The piston also prevents moisture loss by drainage in noncohesive soils. A secondary purpose is to force the sample out of the cylinder. The face of the piston can be taken off to facilitate removal and cleaning of the piston ring. Before use, the bottom of the piston should be even with the cylinder's cutting edge and the base of the disc handle should fit tightly against the "T" handle support.

The Cylinders

The cylinders are made of noncorrosive metal. Their inside diameters are machined to close tolerance for accuracy in computation of constants for unit weight determination. The cylinder walls and cutting edges are comparatively soft and should be handled with some care. If the cutting edge becomes badly nicked, a new cutting edge can be turned and the piston reset, or a new cylinder can be used.

Handle

The smooth handle is screwed snugly into position and should remain fixed at all times. The knurled handle serves as a handle and as a lock to hold the piston rod in any position desired.

Sampling Instructions

Sampling with this instrument can be accomplished most expeditiously by a comparatively husky technician and, under some conditions, one helper. In taking a sample, the technician holds the disc handle at the top of the piston rod firmly against his body with one hand while forcing the cylinder smoothly into the soil with the other, being careful to permit no downward movement of the piston. Figure B-2a shows this operation. The sampler is pushed to a depth of slightly more than 6 inches (15.2 cm). The technician then locks the piston rod with the knurled handle, twists the sampler slightly to break the soil free, and withdraws the cylinder from the soil. To obtain 3-inch (7.6-cm) samples for moisture-density determinations, the technician unlocks the piston rod, places the pin through the hole in the piston rod 6 inches (15.2 cm) below the bottom of the disc handle suppport, inverts the instrument, forces out the small quantity of soil in excess of 6 inches until the pin is snug against the "T" handle support, and then cuts away this soil as waste (figure B-2b). When this operation is completed, the technician places a plate over the cutting edge of the cylinder to catch any falling fragments of the sample, disengages the pin in the piston rod, places it through the hole 3 inches from the bottom of the disc handle, and forces out the soil by pushing the sampler down until the support of the "T" handle is in contact with the pin. The sample is cut off flush with the cutting edge of the cylinder with a wire cutter or knife (figure B-2c). To obtain the second 3-inch sample the technician disengages the pin in the piston rod, places the pan over the cutting edge of the cylinder to catch the sample, and forces out the soil by pushing the sampler down until the base of the disc handle is in contact with the center support of the "T" handle. Each extruded soil sample represents a sample length of 3 inches and therefore a known volume. Each sample is carefully placed in a container for transportation to the laboratory.

Further Investigations

The procedures described in the preceding paragraph are followed when the sampler can be inserted into soil to a depth of slightly more than 6 inches (15.2 cm). If the sampler cannot be pushed to a depth of 6 inches because of the firmness or stickiness of the soil, samples should be obtained in 3-inch vertical increments. The first hole that appears in the piston rod next to the disc handle mounted on the piston rod is used to obtain the sample; otherwise, sampling procedures are the same.

Care

To insure efficient operation, it is necessary to clean the instrument after each day's use, and for certain soil conditions more frequent cleaning may be required. To clean the sampler, remove the cylinder and thoroughly rinse it and the piston assembly with water. Oil the piston assembly and rod with light lubricating oil. Reassemble the sampler.

Adjustment

To obtain samples of the correct length with the Hvorslev sampler, two items must be checked on the sampler before it is used: (a) When the base of the disk handle is in contact with the "T" handle support, the face of the piston is flush with the cutting edge of the cylinder, and; (b) the distance between the base of the disc handle and the bottom of the first hole drilled through the piston rod is 3 inches. If the sampler is out of adjustment, the following steps are taken:

(1) Check the distance from the base of the disc handle to the bottom of the first hole drilled through the piston rod. If this distance is not 3 inches, loosen the set screw on the disc handle, screw the disc handle up or

Figure B-2. Use of Hvorslev Soil Sampler.

down until the distance between the bottom of the disc handle and the bottom of the first hole drilled through the piston rod is 3 inches, and then tighten the screw.

(2) Push the piston rod down until the base of the disc handle is in contact with the "T" handle support. If the piston head is not flush with the cutting edge, measure the difference, remove the cylinder, and loosen the nut next to the piston. If the piston head protrudes beyond the cylinder cutting edge, back off the nut to the distance measured before the cylinder was removed, screw the piston head next to the nut, and tighten the nut. If the piston head is inside the cylinder tube, loosen the nut next to the piston head, back off the piston head the required distance, and tighten the nut. Replace the cylinder and recheck. If the piston is not flush with the cutting edge, repeat the process until the piston head is flush with the cutting edge.

(3) If the tube is to be replaced, check the tube length before it is used. To obtain the proper sample lengths, the tube must be at least 9.25 inches (23.5 cm) long.

D. REMOLDING EQUIPMENT

Description

The remolding equipment (figure B-3) consists of a cylinder of the same diameter as the Hvorslev sampler mounted vertically on a base, and a 2 1/2-pound (1.13-kg) drop-hammer which travels 12 inches (30.5 cm) on an 18-inch (45.7-cm) shaft, fitted with a circular foot on one end and a handle on the other. A cone penetrometer with an 18-inch (45.7-cm) shaft and a Hvorslev sampler are needed to conduct tests.

Procedures for Fine-Grained Soils

A 6-inch long soil sample is obtained from the desired layer with the Hvorslev sampler and ejected into the remolding cylinder (figure B-3 and B-4). The sample is then pushed to the base of the cylinder, using the drop-hammer foot. Cone penetrometer readings, using a 0.5-square-inch cone, are measured in the sample (figure B-5) at the surface (where the base of the cone enters the soil) and at each successive inch to a depth of 4 inches (10.2 cm) at a rate of 6 feet-per-minute. If a reading over 300^{+} (capacity of penetrometer) is reached at a depth of 2 inches or more, 300 is assigned to the depth and the remaining depths. If a reading over 300 is reached at a depth of 1 inch or less, instructions given below are followed. Next, remolding the sample is accomplished by applying 100 rapid blows of the drop-hammer (figure B-6). The top of the hammer should touch the base of the handle with each blow to insure a 12-inch drop. Penetrometer readings are taken again at the surface and at each succeeding inch depth to 4 inches.

Figure B-3. Collecting Soil Sample with the Hvorslev Sampler.

Figure B-4. Ejecting Sample into Remolding Cylinder.

Figure B-5. Taking Cone Penetrometer Readings.

Figure B-6. Remolding the Soil Sample.

Use of 0.2-Square-Inch (1.3-cm^2) Cone

Occasionally, a fine-grained soil sample obtained in the manner just described cannot be penetrated by the 0.5-square-inch cone beyond the 1-inch depth. In such a case, a new sample is obtained and the penetrations are made with the 0.2-square-inch cone. If a reading greater than the capacity of the cone penetrometer (750) is reached at a depth of 1 inch or less before and after 100 blows are applied, the test is not valid. The size of the cone used must be noted on the field data sheet.

Procedures for Fine, Poorly Drained Sands

The remolding test procedures for these soils are the same as for fine-grained soils except that cone index measurements are made with penetrometer with the 0.2-square-inch (1.3-sq-cm) cone, and the sample is remolded by dropping it (along with cylinder and base) 25 times from a height of 6 inches (15.2 cm) onto a firm surface. Loss of water during the remolding process will influence the test results; therefore, the tube and metal base should be scaled with a clay plug about 1 inch long placed at the bottom of the tube. On the data sheet cross out "100 blows" and insert "25 drops."

E. SHEARGRAPH

Description

The sheargraph (COHRON) is designed to obtain horizontal shearing strength parameters of surface soils in conventional soil mechanics terms when soil failure is not produced by the vertical load. The instrument (figure B-7) provides data from which the resistance to shear is described by empirical parameters relating the shear stress to the normal stress.

The initial (ϕ_i, C_i) and residual (ϕ_r, C_r) shear strength parameters are linearized. The linearized shear stress-normal stress relations for a soil that exhibits both apparent cohesion and frictional resistance to shear is defined by Coulomb's equation:

$$\tau = c + \delta \tan \phi \qquad \text{(Eq. B-1)}$$

where:

τ = shear stress, psi
δ = normal stress, psi
c = soil apparent cohesion at zero normal stress
ϕ = angle of soil internal friction

An estimate of traction (DBP) can be obtained from the following formula:

$$DBP = Ac + W \tan \phi \qquad \text{(Eq. B-2)}$$

where:

A = ground contact area, square inch.
W = total weight on shear area, pounds.

Figure B-7. Sheargraph.

Shear Values

The sheargraph is provided with grouser, and smooth metal and rubber shear-heads. The smooth shear-heads are used to obtain soil-to-metal and soil-to-rubber shear values. The subscripts used to identify the various shear values are listed below:

c_i = peak soil-to-soil cohesion

c_r = residual soil-to-soil cohesion

ϕ_i = peak soil-to-soil angle of internal friction

ϕ_r = residual soil-to-soil angle of internal friction

a_{rm} = residual soil-to-metal adhesion

a_{im} = peak soil-to-metal adhesion

P_{im} = peak soil-to-metal angle of friction

P_{rm} = residual soil-to-metal angle of friction

a_{ir} = peak soil-to-rubber adhesion

a_{rr} = residual soil-to-rubber angle of friction

Use

The sheargraph should be checked before it is used to insure that components are properly fastened and in operating condition. The chart is placed on the drum in such a manner that the stylus point is at zero, both on the shear stress and normal stress axes, with the normal stress axis placed along the length of the drum. The chart is held in position with a rubber band placed at the top and bottom of the drum.

Soil Selection

The soil selected for sampling should be free of rocks and gravel materials, and the surface cleaned of grasses, litter and roots. The smooth metal and rubber shear-heads are placed on the soil surface but the vane or grouser shear-head is inserted in the soil until the vanes are completely submerged. The grouser shear-head is inserted by applying a normal load on the handle. On slopes, the instrument is positioned perpendicular to the surface. Care must be taken during the vane insertion to avoid shearing the soil prior to the application of shearing stress. In sticky soils (clays and silts), the soil around the outer edge of the vane shear-head should be removed because the soil adhering to the outer edge will influence the shear stress reading.

Instructions

Once the shear-head is inserted properly into the soil, a normal stress is applied by pushing downward on the handle to the desired load. Observe the normal stress axis to assure the correct normal load and motion of the shear-head and that the stylus is producing a readable trace. The hand should be placed on the handle in such a manner that for a given normal load the wrist will permit rotating the sheargraph approximately 180 degrees in a counter-clockwise direction. Then rotate the handle until the shear-head begins to rotate. The value obtained upon initiation of rotation is peak shear stress. The instrument is unloaded, the hand repositioned, the same normal stress applied, and the handle rotated counter-clockwise to reinitiate motion of the shear-head to obtain a value for ultimate or residual shear stress. After cleaning the shear-head, the process is repeated for at least four normal stress loads, or until an acceptable straight-line relation for normal stress versus shear stress can be drawn on the chart for initial peak and residual ultimate shear stress data.

Sampling

The sampling pattern to be followed is largely dependent upon soil type and moisture content. For example, in a moist-to-dry clay soil, a peak shear stress measurement might be obtainable only for normal stresses less than 5 pounds-per-square inch (psi). In this case ultimate shear stress should be attempted for normal stress values less than 5 psi and so on. In soft clay soils, a normal stress of 10 psi may shear the soil. In such conditions all shear stress measurements should be restricted to normal stresses less than 10 psi. If the soil fails for a given normal stress, the normal stress at which the soil failed should be recorded on the chart.

Adjustment and Care

The sheargraph requires no adjustment if the instrument is kept clean and all parts are kept tight. The instrument should be calibrated occasionally to check the normal and shear stress against the chart scale.

F. OAKFIELD PUNCH

Description

The Oakfield punch is a device designed to rapidly obtain small soil samples for moisture content determinations. It consists of a tube (figure B-8) with a cutting edge and a cut-out sidewall mounted on a shaft with a handle. Depth indicators are inscribed on the tube.

Instructions

The punch is pushed into the soil in a normal position to the desired depth. The handle is turned to break the soil column and the punch is withdrawn from the soil. The soil is removed from the tube through the sidewall opening with the fingers or a spatula and placed in a soil can.

Three samples are usually taken from each layer if the soil sample is in 3-inch (7.6-cm) vertical increments. The punch should be kept clean at all times.

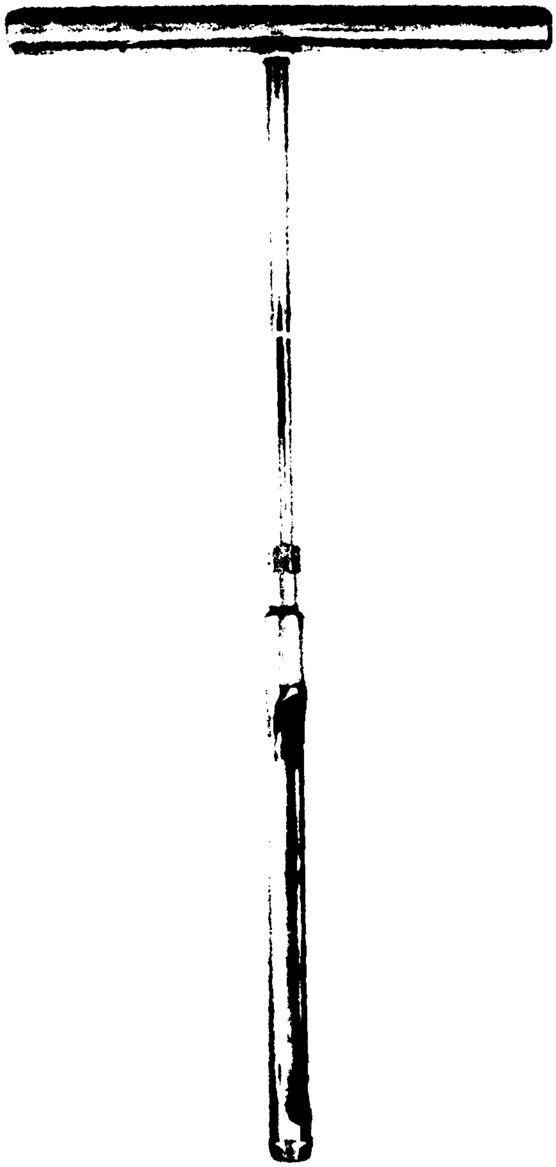


Figure B-8. Oakfield Punch.

G. OTHER EQUIPMENT.

Use

Standard equipment and devices are used to measure distance, angles, direction, slope, cross sections, and size and spacing of obstacles. The instructions provided with standard equipment are used as directed in use and care of equipment.

III. TEST ROUTINE

A. DATA COLLECTION PROCEDURES AND SITE LAYOUT

Collection Procedures

The data items listed on the Data Form (Annex I) will be collected at each sample site if the terrain factor is present and the specific parameter to be measured does not exceed the capacity of the instrument. In the event a specific set of data cannot be measured, the maximum instrument capacity with a plus sign should be indicated on the data form and appropriate comments made in the remarks.

Order of Collection

The order in which terrain data are collected is important because excessive personnel traffic on the site can destroy or influence the data results; i.e., human traffic on forested sites will destroy small plants which in turn influence visibility measurements. To minimize the effects of traffic on the measurement of terrain data, visibility or recognition distance data should be collected first, followed by surface composition with soil strength measurements, then vegetation measurements, and finally surface geometry measurements.

Site Layout

A sampling site is laid out on an assumed homogenous landform component (figure B-9). The center and principal axis of the site are laid out with appropriate measurement devices along with as many as eight radii spaced 45 degrees apart, if necessary, to identify sampling locations. The center of the site will be located at station 0 + 50 if the site is on flat terrain and has no identifiable orientation of surface features (rows or dikes). The principal axis is located along a north-south grid. On sloping terrain the principal axis is located at right angles to the contour lines. If the site selected is on a narrow landform component such as a narrow bottomland terrace, the principal axis is located along the length of the terrace.

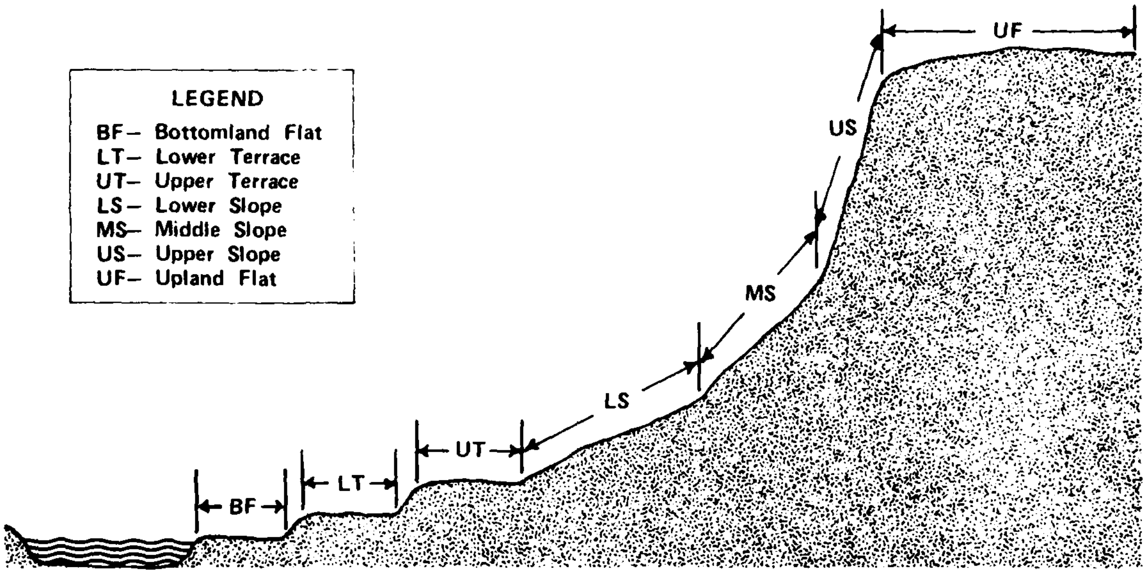


Figure B-9. Landform Components.

B. SURFACE COMPOSITION

Cone Index

At each site 10 sets of cone index measurements will be made at 10-foot horizontal intervals, beginning at station 0 + 00 and ending at station 0 + 90 along the principal axis. Station zero is located at the south end of the site on flat areas and at the bottom of the slope on sloping terrain. A set of readings includes cone index measurements taken at the surface, and at depths of 3, 6, 9, 12, 15, and 18 inches (7.6, 15.2, 22.9, 30.5, and 45.7 cm).

When cone index readings greater than 300 are obtained with the 0.5-square-inch cone at prescribed depths and at several locations, the 0.2-square-inch cone is used to measure cone index. If the 0.2-square-inch cone is used with a dial that indicates a maximum reading of 300, be sure to note on the data form the size of the cone and maximum dial reading so that the appropriate conversion can be made. For instance, readings obtained with a 0.2-square-inch cone and dial maximum reading of 300 must be multiplied by 2.5 to obtain the correct cone indexes.

Remolding Index

The cone index data recorded in paragraph 2g(1) (Annex I) are examined to determine which set of cone index readings contained the lowest in the 0- to 12-inch depth. The remolding index data are taken at the same location as the other soil data.

The sampling pattern is given in figure B-10. Care should be taken not to disturb the soil at the location selected for detailed soil sampling. The remolding test will be made on a sample obtained from the 0- to 6-inch and 6- to 12-inch layers. Procedures described under remolding equipment will be followed in conducting the test. Two remolding tests are conducted for each layer. If the difference in remolding index values between test 1 and test 2 is greater than 0.12, a third test is run and all three index values are averaged. (NOTE: If a 6-inch long sample cannot be obtained with the Hvorslev sampler, or if the soil sample in the tube is too firm to penetrate with the 0.2- square-inch cone, it is so noted on the form.)

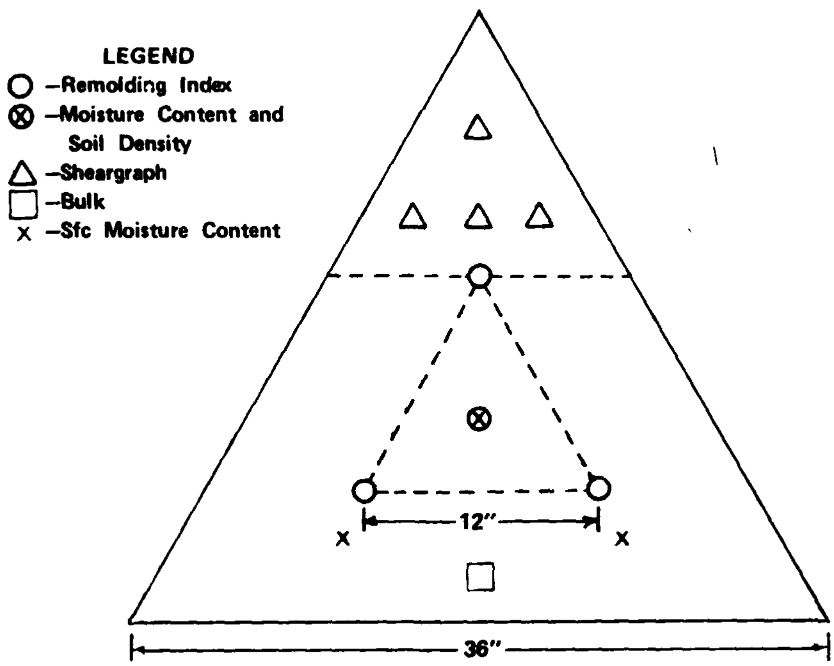


Figure B-10. Soil Data Sampling Pattern.

Sheargraph

Sheargraph measurements are made on the soil surface at each site in accordance with procedures discussed earlier and the sampling pattern shown in figure B-10, above. A set of readings is taken of the natural soil moisture during the time of sampling and after the surface has been artificially wetted with water. A sufficient number of peak and residual shear values are obtained for the range of normal stress shown on the chart to define a linear relation between normal stress and shear stress.

Density and Moisture Content

Samples for density determinations will be taken with the Hvorslev sampler in accordance with procedures outlined under care and use of samples. The density samples will also be used for moisture content determinations. One sample at each test site will be taken from each layer—0 to 3 inches (0 to 7.6 cm), 3 to 6 inches (7.6 to 15.2 cm), 6 to 9 inches (15.2 to 22.9 cm), and 9 to 12 inches (22.9 to 30.5 cm). The sample is placed in a soil can and sealed with a plastic tape.

Location

Location of sampling points is given in figure B-10. If the soil is too firm to sample for density, the Oakfield punch or similar device is used to obtain moisture content samples; notes such as "too firm to use Hvorslev sampler" should be recorded on the data sheet.

Water Table

The depth to groundwater is measured to the nearest 0.5 inch (1.3 cm) with a yardstick or similar device in the holes made to obtain remolding or density/moisture content samples prior to leaving the test site.

Laboratory Samples

After all soil measurements have been taken, bulk samples are selected for laboratory analysis of pertinent soil properties. About a 500-gram sample of each is taken from the 0- to 6-inch and 6- to 12-inch layers at one location using the Hvorslev or a suitable soil sampling device. The soil is placed in a plastic bag. Each sample is identified by site, depth of sample, and date of sampling. Laboratory determination of Atterberg limits and mechanical analysis will be made.

Pertinent Notes

Pertinent notes including weather and surface soil conditions will be recorded on the field data sheet as indicated. The presence of free water on the surface of sample sites, floodings, the presence of surface cracks caused by drying, and other pertinent observations will be noted. Data pertinent to location, drainage, land use, soil parent material and profile and an index and explanation of photographs taken will be recorded at each site.

C. SURFACE GEOMETRY

Descriptions

Surface geometry describes the topographic surface. Macrogeometry describes the topographic surface as generated by a contour interval of 10 meters, or only those features that are recorded by 10-meter contour lines; whereas microgeometry provides a description of those attributes of the topographic surface that are small enough not to be revealed by 10-meter contour lines. The latter is usually referred to as micro relief or surface roughness.

Macrogeometry

Macrogeometry is measured with an Abney level along the principal axis of the site. If the principal axis does not lie at right angles to the contours, the maximum slope and azimuth between the maximum slope and principal axis are also measured and recorded on the Data Form (Annex I). Slope is recorded to the nearest percent.

Microgeometry

Microgeometry is measured with a measuring tape 100 feet (30.5 meters) long, stretched tightly along the principal axis with station 0 + 50 at the center of the site. The tape should be fastened to a firm obstacle 2 feet (50.4 cm) above the ground at stations 0 + 00 and 1 + 00 and supported at each end, and at quarter points, if required to prevent sagging. The slope along the principal axis is measured from station 0 + 00 to 1 + 00, and on surface geometry data form.

Measurements

Measurement of microgeometry is made at 1-foot horizontal intervals along the stretched tape with the vertical distance measurement perpendicular to the stretched tape. These measurements are recorded in paragraph 3b(2) (Annex I).

Obstacles

If obstacles occur on site, they are described by measuring the perpendicular distance from the principal site axis to the center of the obstacle. A compass can be used to establish direction. The obstacle is also described in terms of its type, length, width, height, and approach angle. Obstacles that occur within the 100-foot diameter site are measured and described as above. Special data forms are provided for recording data describing linear and random obstacles.

D. VEGETATION

Description

The vegetation at each site will be described in conventional botanical and structural attribute terms. The sampling routines used to provide data on selected structural attributes are discussed, because these data are commonly used in modeling vegetation effects on a test activity. The two methods are the structural cell and the modified quarter. In both methods, stem diameter will be measured at breast height (DBH), 4.5 feet (1.37 cm) above the ground.

Structural Cell Method

At the center of the site, estimate a cell diameter that will include approximately 20 stem sizes in class 1 (less than 1 inch) described in paragraph 4f of the Data Form. If 20 plants of class 1 occur in the cell, record the cell diameter; and, if not, add a small annulus to the cell diameter to obtain 20 stems of class 1 size. The process is repeated for all stem diameters until each class contains 20 stems or until a cell diameter of 100 feet is reached. Once the stem count of 20 is reached for a given stem diameter class, the stem sizes in that class are no longer counted in satisfying the stem count for the next stem size classes. The stem data are recorded on the form shown in paragraph 4f (Annex I).

Modified Quarter Method

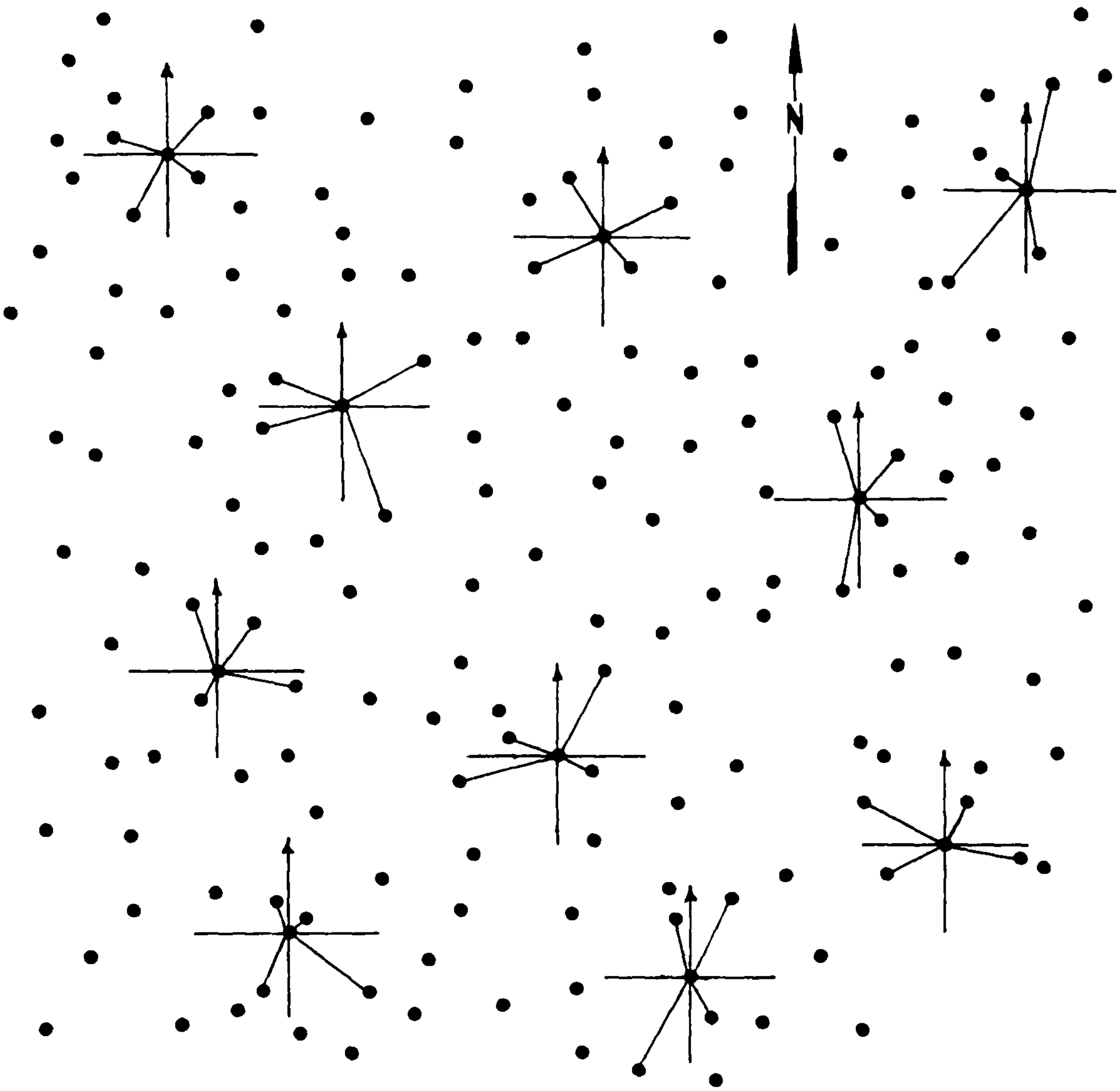
At each sampling site the modified quarter method will be used to obtain a measure of stem spacing and density of stems equal to or greater than 1-inch DBH. Ten trees within the sampling site (100-foot diameter) are selected at random as the centers of sampling points and appropriately marked (figure B-11). Each sampling point is subdivided into four quadrants using a compass with orientation of one axis identical to the principal axis of the test site. At each sampling point, measure the distance, (nearest neighbor distance (NND)), between the tree used as the center of the sampling point and the nearest tree in each quadrant, and the stem diameter (DBH). These data are recorded on the form given in paragraph 4g (Annex I).

Marking Trees

Once a tree is included in the data base it is marked with spray paint or flagging to avoid recounting. As the cell diameter gets larger, it may be necessary to establish additional radii to properly identify the location of plants and size of sample cell.

Vegetation Clumps

Occasionally, clumps of vegetation stems will be encountered. To measure clumps of vegetation, count the number of stems in the clump, measure the stem diameter (DBH) and record in the appropriate section of the data form. During



LEGEND

- Denotes location of tree stems within sampling site
- Denotes location of 10 trees selected as sampling points with area surrounding tree divided into four quarters (quadrants)
- Denotes distance between tree selected as sampling point and the nearest tree to it in each of the four quadrants

Figure B-11. Diagram of Method of Measuring Vegetation Stem Density.

the data tabulation process, clump-stem diameters are converted to an effective single-stem diameter using a special empirical formula.

Vegetation Types Common in Canal Zone

In providing a general description of the Holdridge forest life zone associations required in paragraph 4c (Annex I), the descriptive keys below should be used to identify major tropical vegetation types that occur within the study area.

Secondary and Edaphic Associations

The system is based on vegetation structure (type) which is primarily dependent on temperature and precipitation with modifications from nonclimatic secondary and edaphic associations:

a. Secondary Associations: Areas recently cut, burned or disturbed by man in other ways (grasslands, Heliconia or Palmetto areas, jungle tangle).

b. Adaphic Associations: Associations resulting from or influenced by factors inherent in the soil, i.e., flood plains, areas frequently inundated with fresh, salt or brackish waters, slope and ridge associations, and areas well drained with shallow soils (e.g., freshwater palm swamps, catival forests, mangrove swamps).

Structural Descriptions

The following structural descriptions of the life zones listed above are for mature forests in well drained upland associations.

a. Tropical Moist Forest. General: Tall multistratal semideciduous or evergreen trees.

Canopy: Trees 130 to 160 feet (40 to 50 m) tall with wide crowns, slender trunks, often with buttresses, and boles unbranched for 80 to 110 feet (25 to 35 m).

Subcanopy: Trees up to 100 feet (30 m) tall with narrow crowns; palms are common to abundant. Density of subcanopy is variable depending on length of dry season and site factors.

Understory trees: Trees 25 to 65 feet (8 to 20 m) tall with round to conical crowns.

b. Premontane Wet Forest. General: Tall to intermediate semievergreen trees with two or three strata. Strata are not always easily distinguishable.

Canopy: Trees 100 to 130 feet (30 to 40 m) tall with round to spreading crowns and slender to stout trunks. Buttresses are common but smaller than in Tropical Moist and Tropical Wet Forests.

Subcanopy: Small trees and shrub layers are evergreen.

Small Tree Stratum: A dense layer of trees 30 to 65 feet (10 to 20 m) tall. Stilt roots are common and tree ferns occasional.

Shrub layer: A dense stratum of single-stemmed small trees 6 to 10 feet (2 to 3 m) tall; small palms are rare.

c. Premontane Moist Forest. General: Two-layered, semideciduous, seasonal trees of medium height. Canopy trees mostly deciduous; understory trees and shrubs, evergreen.

Canopy: Trees about 80 feet (25 m) tall with characteristic broad flat or umbrella-shaped crowns, and short stout trunks sometimes with thorns.

Understory trees: Trees 30 to 65 feet (10 to 20 m) tall, evergreen with round to conical crowns and short twisted or crooked boles.

Shrub layer: Dense woody plants, 6 to 10 feet (2 to 3 m) tall, single and multistemmed, often with spines and occasional bamboo-like grasses.

d. Tropical Wet Forest. General: Tall, multistratal evergreen trees. A few canopy trees may be briefly deciduous, especially when flowering. Number of tree species is very large.

Canopy: Trees 145 to 180 feet (45 to 55 m) tall with occasional larger emergents. Crowns are round to umbrella-shaped, usually not in contact with each other. Clean boles up to 100 feet (30 m) and high buttresses are common.

Subcanopy: Trees 100 to 130 feet (30 to 40 m) tall fill spaces between upper canopy trees. Crowns, round; trunks, slender; large buttresses lacking.

Understory: Trees 30 to 80 feet (10 to 25 m) tall with slender stems, often twisted or crooked; narrow conical crowns. Stilt-rooted palms are abundant.

Shrub layer: Dwarf palms 5 to 8 feet (1.5 to 2.5 m) tall with undivided leaves usually abundant. Giant herbs with banana-like leaves are prevalent, especially in disturbed areas.

e. Tropical Dry Forest. General: Seasonally semideciduous trees of low to intermediate height with two-tree strata.

Canopy: Trees mostly 65 to 80 feet (20 to 25 m) with wide-spreading, often flat-topped, crowns. Trunks are short, often strongly buttressed and occasionally armed.

Shrub layer: Shrubs 6 to 10 feet (2 to 3 m) tall, dense only in openings; often with multiple-armed stems. Wood vines are common.

f. Flood Plain Associations--Nonsaline. Slightly elevated or seasonably fresh water-flooded, fertile, alluvial soil.

(1) Predominately one-grass species with numerous thorny vines in the area, tall grass appearing as a canefield with canes 3/8 inch (1 cm) in diameter. Usually 10 to 13 feet (3 to 4 m) tall. Marsh grass areas. Predominately one species, ragged, grassy appearance from the air, thorns on slender stem, green foliage. Bactris.

(2) Predominately one species, dark green foliage, precumbent boles, rosette foliage distribution on low, round crowns, understory open. Corozo Palm.

g. Low Terrace Associations--Nonsaline. Slightly elevated terrace, less frequently or seasonably fresh water-flooded, with a fertile alluvial soil.

Predominately one species, dark green foliage, slightly uneven canopy, rounded crowns, terete boles, understory usually open. Mature trees 65 to 100 feet (20 to 30 m) tall. Cativo.

Recognition Distance

Recognition distance data are obtained at test sites where a significant obstacle of the ground would be obstructed by vegetation. A measure of the light intensity is obtained with a photographic light meter along the paths on which recognition distance is measured. Average values for f stop, shutter speed, and ASA film rating are recorded in paragraph 4f of the Data Form (Annex I). The target to be recognized is a five-pointed flat-black star that can be inscribed in a 1-foot (25.4-cm) diameter circle.

Measurements

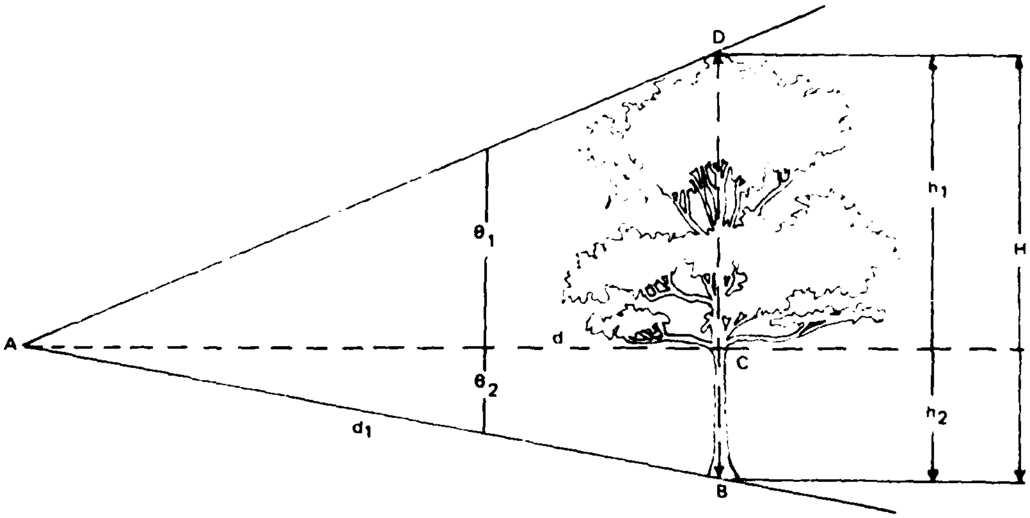
Once the principal axis of a test site is located and the site has been divided into four quadrants, recognition distance measurements are made first to avoid effects of personnel traffic on vegetation characteristics. Measurements are made along four radial lines from the sample cell center, usually at 45 degrees, 135 degrees, 225 degrees and 315 degrees if the principal axis lies along a north-south line. The observer stands at the center of the sampling cell as the target is moved away from him, the distance is recorded at which he can distinguish clearly three points of the star when the star is placed flat on the ground, and when its center is placed vertically at 1 foot (25.4 cm) and 5 feet (1.3 m) above ground. To convert available ambient light to footcandles, the maximum aperture (f) for the camera used, f stop, shutter speed, and ASA film rating must be recorded.

Canopy Cover

In estimating the percent of canopy cover, the observer will walk through each of the four quadrants of the test sites and record in each quadrant a value for the percent of sky that is not visible. These values are recorded in paragraph 4i (Annex I).

Vegetation Height

Tree height is computed from measurements of a baseline distance from the tree and the line-of-sight angle to the top of the tree and the use of trigonometric relations of right triangles. On sloping terrain, the slope angle is measured and used in the computation as illustrated in figure B-12.



Level Ground

$\tan \theta_1 = CD/d$

$h_1 = d \tan \theta_1$

Slope Adjustment

$\tan \theta_2 = BC/d$

$h_2 = d \tan \theta_2$

Sloping Terrain

$$H = h_1 + h_2 = d\ (\tan R_1 + \tan \theta_2)$$

Figure B-12. Computation of Tree Height.

Estimation of Heights

When a line-of-sight to the tree top is not visible, an estimate of tree height can be obtained from a relation between stem diameter and tree height for mature tropical wet, and mature and immature tropical moist forests from the curve shown in figure B-13.

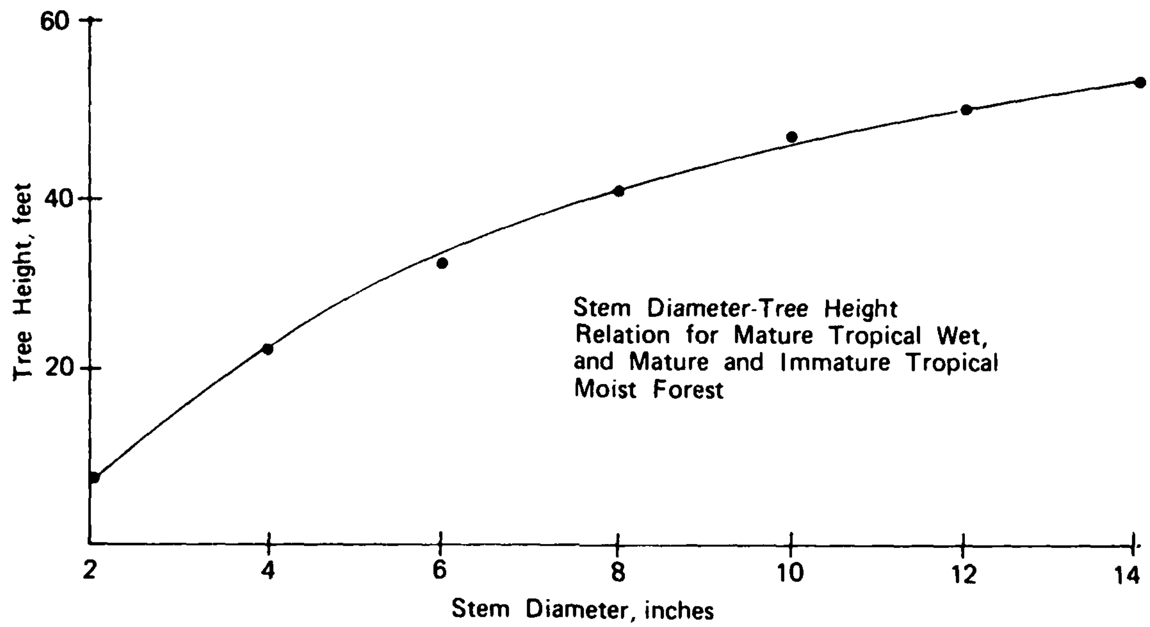


Figure B-13. Estimation of Tree Height.

IV. TABULATION OF DATA

A. SURFACE COMPOSITION

Procedures

The rules and procedures to be followed for computing and tabulating terrain data collected in the field are described in the following paragraphs.

Cone Index. Cone index is an index of the shearing resistance of a medium obtained with a cone penetrometer. The procedures for computing and averaging cone index are as follows:

a. Prior to tabulating the data, all the readings for a given depth are examined for consistency. For example, if a reading of 300^+ occurs in a range of data from 50 to 150, the 300^+ is not included in determining the average for that depth. If a low reading occurs in an array of high readings, it also is eliminated from the averaging procedures. Such outliers indicate the presence of thin hard layers, rocks or voids in the soil.

b. The cone index readings are totaled and averaged for the surface, and the 3-, 6-, 9-, 12-, 15-, and 18-inch layers. If any of the cone index measurements used in determining an average include values that exceeded the capacity of the instrument (300^+ or 750^+ depending upon cone size used), place a plus sign after the average.

c. The average 0- to 6-inch cone index for the site is obtained as follows:

$$\frac{\text{(sfc average)} + \text{(3-inch average)} + \text{(6-inch average)}}{3}$$

d. Averages for the 6- to 12-inch and 12- to 18-inch indexes are obtained by averaging the 6-, 9-, 12-inch and 12-, 15-, 18-inch average cone index readings, respectively. The averages are recorded to the nearest whole numbers.

Remolding Index. The remolding index is the ratio between remolded and natural strength of the soil, as determined by a special remolding test. This is done by dividing the sum of the penetrometer readings taken after remolding by the sum of the readings taken before remolding. The remolding index is recorded in decimals to the nearest 100th.

Computing Index. Procedures used in computing remolding index (RI) and examples of their application are:

a. Cone index readings do not exceed the capacity of the instrument.

0.5-Sq-In Cone

		Blows	
Depth, In		0	100
0		70	40
1		85	60
2		110	90
3		150	120
4		170	140
	Total	585	450

$$RI = \frac{450}{585} = 0.77$$

b. Because of the firmness of the soil sample, readings will exceed the capacity of the instrument and special computation procedures are used, as illustrated:

	0.5-Sq-In Cone		0.2-Sq-In Cone	
	Blows		Blows	
Depth, In.	0	100	0	100
0	110	90	150	120
1	180	150	290	210
2	240	220	750^+	580
3	*300^+	260	750^+	710
4	300^+	300^+	750^+	750^+
Total	830^+	720^+	$1,940^+$	$1,620^+$

$$RI = \frac{720}{830} = 0.87 \qquad RI = \frac{1620}{1940} = 0.84$$

---

*Data above the line only are used in obtaining the total. In order for the test to be valid, the before and after-remolding readings at two or more depths must be less than the capacity of the instrument for one or both of the paired readings; see example (1) below. If the test conducted with the 0.5-square-inch cone is not valid, the test is repeated using the 0.2-square-inch cone; see examples (2) and (3) below.

	(1) Test Valid 0.5-Sq-In Cone		(2) Test Not Valid 0.5-Sq-In Cone		(3) Test Valid 0.2-Sq-In Cone	
	Blows		Blows		Blows	
Depth, In.	0	100	0	100	0	100
0	100	50	100	50	90	45
1	300^+	150	300^+	300^+	450	290
2	300^+	300^+	300^+	300^+	520	320
3	300^+	300^+	300^+	300^+	650	750^+
4	300^+	300^+	300^+	300^+	750^+	750^+
Total	400^+	200^+	---	---	$1,710^+$	$1,405^+$

$$RI = \frac{200}{400} = 0.50 \qquad RI = \frac{1405}{1710} = 0.82$$

c. It is to be noted that 300^+ or 750^+ is used in the computation only when it pairs with a less-than-instrument-capacity value obtained either before or after remolding at the same depth.

d. The same number of cone index readings at their corresponding depths are used before and after remolding, as illustrated below.

0.5-Sq-In Cone

Depth, In.	Blows 0	Blows 100
0	20	10
1	15	5
2	20	5
3	no reading	10 (omit)
4	30	10
Total	85	30

$$RI = \frac{30}{85} = 0.35$$

Average Index. An average remolding index is determined for each site and designated layers.

Rating Cone Index. The rating cone index is the product of the measured cone index and the remolding index for the same soil layer. If the soil is too firm to sample or a valid test cannot be performed, a remolding index of one is used to compute rating cone index.

Surface Shear Strength. The sheargraph provides a set of data that defines, for selected normal stresses, initial or peak and residual or ultimate shear patterns, as follows.

The lines drawn are linearized and values for ϕ_i, ϕ_r, C_i, and C_r are obtained and recorded on the data form.

Density. Dry density will be computed only for core samples obtained with a Hvorslev sampler that have a prescribed length and known volume. The procedures are:

a. Compute the dry density to the closest 0.1 lb/cu ft for the same 3-inch long samples used in the computation of moisture content using the following equation:

$$\text{Dry density (lb/cu ft)} = \text{weight of dry soil (gm)} \times 0.46 \text{ (constant)} \quad \text{(Eq. B-4)}$$

b. Record the data in paragraph 2e of the Data Form (Annex I). If the sample length is changed, a new constant (K) must be determined using the following equation:

$$K = \frac{1728}{453.6 \pi r^2 h} \qquad \text{(Eq. B-5)}$$

where r is the radius (0.937 in) of the inside diameter of the sampler tube and h is the height of the sample in inches. For example, if the net dry weight of a 3-inch-long sample is 190 grams, the density of the soil from which that sample was extracted is 0.46 X 190 grams or 87.4 lbs/cu ft or 1.40 gm/cu cm.

Moisture Content. The data for computing moisture content are given and recorded in paragraph 2e (Annex I). The procedures are:

a. Remove tape from can, weigh can and wet soil to the closest 0.1 gram for each sample and record for given can number.

b. Place can lid on bottom of can, place can in oven, and ovendry to 105°C for at least 24 hours.

c. Weigh can (with lid) and dry soil to the closest 0.1 gram and record.

d. Subtract weight of "can and dry soil" from weight of "can and wet soil" and record weight of water.

e. Record tare weight of can.

f. Subtract weight of "can" from weight of "can and dry soil" and record weight of "dry soil."

g. Compute moisture content using the following formula:

$$\text{Moisture content, \%} = \frac{\text{weight of water}}{\text{weight of dry soil}} \times 100 \quad \text{(record to nearest 0.1\%)} \qquad \text{(Eq. B-6)}$$

h. Determine average moisture content values for layers 0 to 3 inches (0 to 7.6 cm), 3 to 6 inches (7.6 to 15.2 cm), 3 to 9 inches (15.2 to 22.8 cm), and 9 to 12 inches (22.8 to 30.5 cm), and record in the proper columns.

Soil Classification. Most soils in the environmental test are residual clays and silty clay soils; therefore, Atterberg limits only are used to establish soil type according to the Unified Soil Classification Systems. Standard laboratory procedures are used to classify other soil types.

B. SURFACE GEOMETRY

Macrogeometry

Data collected to define the macro-slope require no tabulation.

Microgeometry

Data collected are used to describe the metro relief or surface roughness at the test site. The reference line is fastened to stakes at stations 0 + 00 and 1 + 00, 24 inches above ground. To process the data for tabulation purposes, 24 inches are subtracted from each of the elevation readings given in paragraph 3b of the Data Form (Annex I). The corrected elevation data are processed to obtain a measure of the sample standard deviation. The basic equation used is as follows:

$$s = \sqrt{\frac{\Sigma\ (y-\bar{y})^2}{N}} \qquad \text{(Eq. B-7)}$$

where: s = Sample standard deviation
y = Elevation data point
$\bar{y}$ = Mean
N = Number of data points

Root mean square is also computed for mobility purposes using a USAWES calculating procedure.

C. VEGETATION

Procedures

The data collected for the structural cell and the modified quarter methods, recorded in paragraphs 4f and 4g of the Data Form (Annex I), require different tabulation procedures. The tabulation procedures used are dependent upon data use.

Structural Cell. The number of stems counted in each stem diameter class are totaled and recorded in the column marked "total" on the Data Form (4f) (Annex I). The stem spacing is calculated for each class using the formula:

$$S = {}^{D}\!\Big/\sqrt{N_C} \qquad \text{(Eq. B-8)}$$

where: S = Spacing, ft
D = Diameter of expanded cell, ft
N_C = Number of stems in a given diameter class, or in a given diameter class or greater, or in a given class or less

Density. Stem density is computed by:

$$\text{Stem density} = \text{Number of stems/acre} = \frac{\text{Number of stems}}{\pi r^2/k} \qquad \text{(Eq. B-9)}$$

where: r = Sample cell radius, ft
k = Constant, 43,560 sq ft/acre

Data Reduction. If clumps of vegetation stems are recorded on the field data form, these data must be reduced to an effective stem diameter. Stem diameter for common woody plants can be estimated by computing the work to override the average diameter of a single stem in the clump. Multiply the number of stems and then convert to a single stem diameter. The formula used is:

$$W_t = Kd^3 \qquad \text{(Eq. B-10)}$$

where:

W_t = Override total work in foot-pounds
K = 100.0 for common trees; it varies with the unit cross section stress
d = Stem diameter in inches

This relation is expressed in the following table.

Stem Diameter, in	Total Work Work, ft/lb
1	101
2	803
3	2,706
4	6,410
5	12,514
6	21,617
7	31,506
8	51,220
9	69,770
10	100,017

For example, if 16 2-inch diameter woody stems occur in a clump, the effective stem diameter is computed by the following method:

Total Clump Override Work = W_t (single stem) X no. of stems
= 803 X 16
= 12,848 ft-lbs.
Effective size = 5-inch stem (from table above)

Summary Data Tables. Other computations of data recorded in paragraph 4f of the Data Form (Annex I) are made for each stem diameter class recorded in summary data tables. The data recorded in paragraph 4f of the Data Form are tabulated and presented in the following columns, as an example—Summary of Vegetation Data, Structural Cell Method:

(1)	(2)	(3)	(4)		(5)
Stem Dia Class	Cell Dia (feet)	Stems (no.)	Total Stems <1 in.	>1 in.	Stem Spacing (feet)
1	100	525	525	864	4.36
2	100	725			3 71
3	100	84			10.91
4	100	31			17.96
5	100	7			37.80
6	100	4			50.00
7	100	0			>100.00
8	100	13			27.74

(6)	(7)	(8)	(9)	(10)
Stem Dia Class	Cum Stems; ≤ Dia Class	Cum Stems; ≥ Dia Class	Stem Spacing; ≤ Dia Class (feet)	Stem Spacing; ≥ Dia Class (feet)
1	525	1,389	4.36	2.60
2	1,250	864	2.83	3.40
3	1,334	139	2.74	8.48
4	1,365	55	2.71	13.48
5	1,372	24	2.70	20.41
6	1,376	17	2.70	24.25
7	1,376	13	2.70	27.74
8	1,389	13	2.68	> 27.74

The data in the previous tables are obtained in the following manner.

Column (1). Transfer directly from paragraph 4f of Data Form.

Columns (2) and (3). Transfer from paragraph 4f of Data Form all cell diameters equal to 100 ft, equate data for any cell diameter less than 100 ft to 100-ft diameters. For example, a 20-ft cell diameter with 24 stems is equivalent to a 100-ft cell diameter with 600 stems (25 X 24 = 600).

Column (4). < 1 inch enter class 1 total stems.
> 1 inch enter total of classes to 8 inclusive.

Column (5). Compute using equation B-9.

Column (7). Cumulate column (3) no. of stems by classes.

Column (8). Enter total number of stems in class 8 (13) and for each successive class, add the number of stems to the preceding accumulative total to obtain the accumulative number of stems $\geq$ than that class.

Column (9). Use equation B-7, cell diameter given in column (2), and cumulative number of stems given in column (7) for diameter classes and compute spacing.

Column (10). Use equation B-6, 100 feet expanded cell diameter, and cumulative number of stems given in column (8) to compute spacing for diameter classes given in column 6.

Modified Quarter Method. Each of the data sets in paragraph 4g of the Data Form (Annex I) for stem spacing, stem diameter and stem height are totaled, averaged and recorded in the appropriate columns.

Mean NND and Stem Density. The sample size at each sampling site consists of 10 random points each containing four nearest neighbor distance (NND) measurements. These 40 NND measurements are used to determine the mean (NND) and stem density using the following equations:

$$NND = \frac{\Sigma D}{40} \qquad \text{(Eq. B-11)}$$

where: ΣD = The sum of the measured nearest neighbor distances

$$\text{Number of Stems per Unit Area} = \frac{A}{(NND)^2} \qquad \text{(Eq. B-12)}$$

where: A = unit area

The data recorded in paragraph 4g of the Data Form (Annex I) are used to illustrate the application of the previous equations.

$$NND = \frac{\Sigma D}{40} = \frac{318 \text{ ft}}{7.95 \text{ ft}}$$

$$\text{Number of Stems per Unit Area} = \frac{A}{(NND)^2} = \frac{43{,}560}{7.95^2} = 689 \text{ stems/acre}$$

Recognition Distance. The data shown in paragraph 4h (Annex I) are simply averaged for the 1- and 5-foot target heights and recorded in the last column.

Light Intensity. The film and light meter data recorded in paragraph 4h of the Data Form (Annex I) are used to obtain a value for light intensity at the sampling site during the time that photographs are taken. The following table is used to convert the common film light sensitivities, shutter speeds, and exposure values (EV) to light intensity in terms of footcandles for cameras having a maximum camera aperture opening (f stop) from 1 to 2.8.

FILM TYPE: BW TRI-X Pan 400, ASA 400 | FILM TYPE: Extra Chrome Daylight, ASA 200

Shutter Speed (1 sec)	Exposure Value	Footcandles	Shutter Speed (1 sec)	Exposure Value	Footcandles
		f Stop = 1			
30	3	0.1	15	3	0.1
60	4	0.2	30	4	0.2
125	5	0.4	60	5	0.4
250	6	0.8	125	6	0.8
500	7	1.6	250	7	1.6
1000	8	3.2	500	8	3.2
			1000	9	6.5
		f Stop = 1.4			
15	3	0.1	8	3	0.1
30	4	0.2	15	4	0.2
60	5	0.4	30	5	0.4
125	6	0.8	60	6	0.8
250	7	1.6	125	7	1.6
500	8	3.2	250	8	3.2
1000	9	6.5	500	9	6.5
			1000	10	13.1
		f Stop = 2.0			
8	3	0.1	4	3	0.1
15	4	0.2	8	4	0.2
30	5	0.4	15	5	0.4
60	6	0.8	30	6	0.8
125	7	1.6	60	7	1.6
250	8	3.2	125	8	3.2
500	9	6.5	250	9	6.5
1000	10	13.1	500	10	13.1
			1000	11	16.1
		f Stop = 2.8			
4	3	0.1	2	—	—
8	4	0.2	4	3	0.1
15	5	0.4	8	4	0.2
30	6	0.8	15	5	0.4
60	7	1.6	30	6	0.8
125	8	3.2	60	7	1.6
250	9	6.5	125	8	3.2
500	10	13.1	250	9	6.5
1000	11	26.1	500	10	13.1
			1000	11	26.1

APPENDIX B--ANNEX I. USATTC TERRAIN DATA COLLECTION FORMS--AREAL TERRAIN

1. Identification and Site Description:

   a. Site No. 12 Date 6-28-79 Time 0945

   b. Party Chief R. Johnson

   c. Location:

      Map Reference: AMS Series E965 Airphoto Reference No. 203

      Grid Coordinates 42730945

   d. Elevation: Ft. 188 Local Relief: Ft. 110

   e. Weather: Clear ____ Cloudy ____ Partly Cloudy X Rain ____

   f. Landform Component: Middle slope

   g. Principal Axis, Deg: Az: 270.0 Grid Az: 266.5

   h. Topographic Position Middle slope

   i. Slope, %: 24

   j. Shape and Size, Ft., of Sample Site: Rectangular

   k. Landuse: Tropical forest

   REMARKS: ____

2. Surface Composition:

   a. Surface Cover:

      Type and %: Organic X % 100 Inorganic ____ % ____

      other ____ % ____

   b. Surface wetness: Dry ____ Moist ____ Wet X Flooded ____

   c. Water Table Depth, In. >18 in

   d. Soil Depth: In. >18 in Measured ____ Estimated X

   REMARKS ____

e. Moisture Content and Density

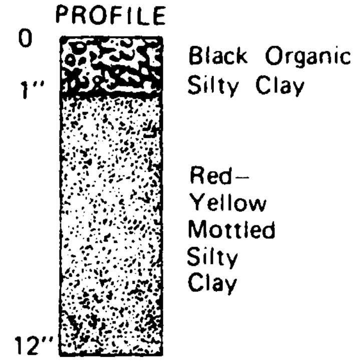
	Layer (inches)	0–0.5"	0–0.5"	0–3"	0–3"	3–6"	3–6"	6–9"	6–9"	9–12"	9–12"
	Can No.	K232	—	K138	—	K173	—	131A	—	—	—
GRAMS	Wet & Can	145.7	—	283.4	—	306.9	—	347.0	—	—	—
GRAMS	Dry & Can	115.5	—	215.6	—	246.5	—	285.5	—	—	—
GRAMS	Water	30.2	—	67.8	—	60.4	—	61.5	—	—	—
GRAMS	Can Wt	58.4	—	59.1	—	59.0	—	99.0	—	—	—
GRAMS	Dry Soil Wt	57.1	—	156.5	—	187.5	—	186.5	—	—	—
	MC, %	52.9	—	43.3	—	32.2	—	33.0	—	—	—
	Dry Den. lb/ft^3	—	—	72.0	—	86.2	—	85.8	—	—	—
	Avg MC, %	52.9		43.3		32.2		33.0		—	
	Avg Den, lb/ft^3	—		72.0		86.2		85.8		—	

f. Soil Classification:

(1) Field

Depth In	Classification		
	USDA		USCS
	Series	Texture	
0-6	Arraijan	Clay	MH
6-2	Arraijan	Clay	MH
12-18	Arraijan	Clay	MH

SOIL PROFILE



(2) Laboratory:

Depth	Atterberg Limits, %			
0-6 In.	LL 74 .	PL 38 .	PI 36 .	USCS MH .
0-12 In.	LL 68 .	PL 37 .	PI 31 .	USCS MH .
12-18 In.	LL ___ .	PL ___ .	PI ___ .	USCS ___ .

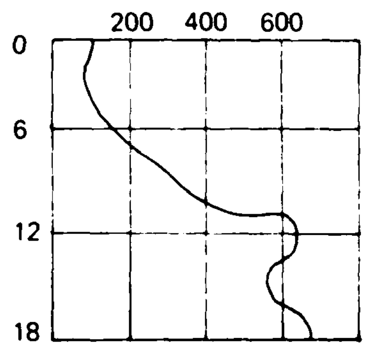
REMARKS: ______________________________

g. Soil Strength:

(1) Cone Index (CI) Cone Size: 0.2 in²
Dial Size: 750

Reading	Depth, In.						
	0	3	6	9	12	15	18
1	40	130	190	300	750+		
2	60	90	190	600	550	750+	
3	50	100	160	230	480	580	750+
4	70	180	430	750+			
5	40	80	220	180	170	260	750+
6	80	130	230	220	200	750	
7	80	90	110	280	540	550	750+
8	80	100	500	430	410	450	350
9	70	100	130	130	120	140	140
10	50	90	140	180	140	130	190
Total	620	1090	1370	1750	3760	3340	2600
Avg	62	109	171	219	627+	557+	650+

CONE INDEX PROFILE



NOTE: Circled numbers omitted

(2) Remolding Index: (RI) Cone Size: 0.5 in^2
Dial Range: 300

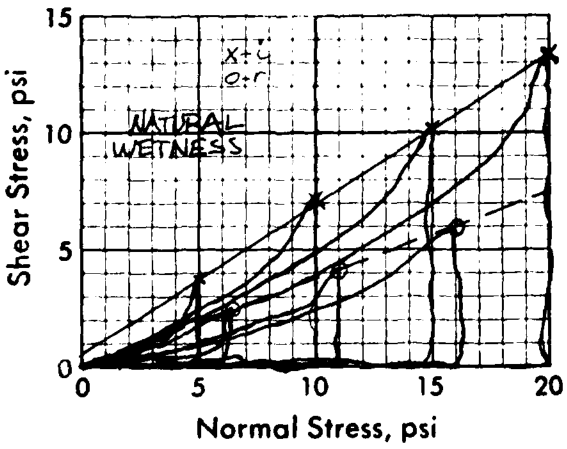
LAYER	0-6"		0-6"		0-6"		6-12"		6-12"		6-12"	
	B	A	B	A	B	A	B	A	B	A	B	A
SURFACE	100	60	65	50								
1"	130	85	135	70								
2"	125	95	145	90								
3"	128	105	100	120					TOO DIFFICULT TO			
4"	140	130	120	130					SAMPLE			
TOTAL	623	475	565	460								
RI		0.76		0.81								
AVG			0.79									

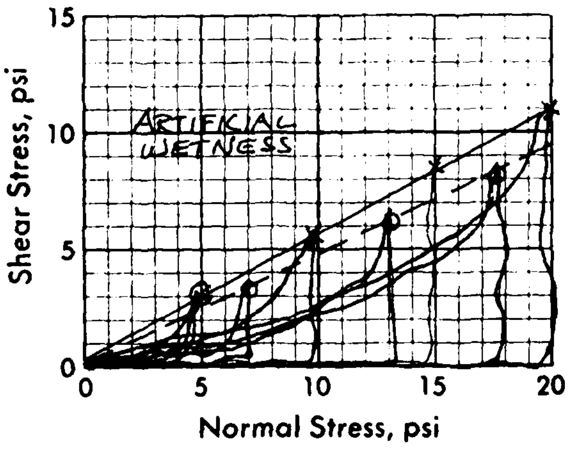
(3) Rating Cone Index (RCI):

LAYER	0-6"	0-12"	12-18"
CI	114	339$^+$	611$^+$
RI	0.79	1	1
RCI	90	339$^+$	611$^+$

REMARKS: Roots and firm soil were encountered in 6-12 in layer.

(4) Sheargraph: Type of foot: Vane_____ Rubber X Metal_____





(a) Natural Wetness

Cohesion (c), psi Initial, c_i 0.5 Residual, c_r 0.1

Angle of Internal Friction (ϕ), deg Initial, ϕ_i 31.2 Residual, ϕ_r 19.6

(b) Artificial Wetness

Cohesion (c), psi Initial, c_i 0.1 Residual, c_r 0

Angle of Internal Friction (ϕ), deg Initial, d 28.0 Residual, d_r 24.2

3. Surface Geometry:

a. Macro

(1) Slope, % 24

(2) Direction Azimuth, deg. Magnetic 90 Grid 86.5

b. Micro

(1) Profile Orientation: Az, deg: Magnetic 90 Grid 86.5

(2) Pattern of Features: Random X Linear ____

REMARKS: ____________

MICROGEOMETRY PROFILES		OBSTACLES									
Station (ft)	Elevation (in)	Direction*	Distance (ft)	Pattern**	Type	Shape	Length (ft)	Width (in)	Height (in)	Orientation Azi (deg)	Approach Angle (deg)
0	20										
1	24										
2	22										
3	22.5										
4	23										
5	23										
6	23										
7	22										
8	23.5										
9	23										
10	22.5										
11	24										
12	24										
13	24.5										
14	25										
15	24										
16	26										
17	25.5										
18	28										
19	29					rect	30				
20	29	R	15	L_1	log	linear		9	48		90
21	28.5										
22	28										
23	28										
24	27										
25	26										
26	25										
27	24										
28	24										
29	23										
30	24.5										
31	23.5										
32	23										
33	24										
34	23										
35	22.5										
36	24										
37	24										
38	24										
39	23.5										
40	23.5										
41	22										
42	24										
43	24										
44	23.5										
45	24										
46	23										
47	25										
48	23.5										
49	24										
50	24										

LEGEND

* L - Left of principal axis
* R - Right of principal axis
** L_1 - Linear
** R_1 - Random

MICROGEOMETRY PROFILES		OBSTACLES									
Station (ft)	Elevation (in)	Direction*	Distance (ft)	Pattern**	Type	Shape	Length (ft)	Width (in)	Height (in)	Orientation Azi (deg)	Approach Angle (deg)
51	24.5										
52	24										
53	23.5										
54	24										
55	24										
56	24										
57	23										
58	23										
59	23										
60	21.5										
61	21										
62	22										
63	22										
64	22.5										
65	22.5										
66	22										
67	22										
68	21.5										
69	20.0										
70	20.5										
71	21.5										
72	21										
73	20										
74	21										
75	21										
76	21										
77	22										
78	21.5										
79	22										
80	24			L_1	log	rect	45	24	36		90
81	23										
82	23										
83	22										
84	23										
85	23										
86	22										
87	23										
88	23.5										
89	24										
90	23	L		L_1	log	rect	25	5	5		90
91	23.5	R		L_1	log	rect	10	18	24		90
92	23										
93	23										
94	24										
95	25			L_1	log	rect	40	10	12		90
96	25.5										
97	25										
98	26										
99	24.5										
100	20			L_1	log	rect	10	12	12		90

NOTE: WES Root Mean Square = 1.10

LEGEND

- * L - Left of principal axis
- * R - Right of principal axis
- ** L_1 - Linear
- ** R_1 - Random

4. Vegetation:

a. Type: Forest X Brush ____ Grass ____

b. Predominant Species:

c. Composition, %. Deciduous 85 Nondeciduous ____
Palm 15 Mixed ____

d. Canopy Height, Ft 8* Closure, % 90

e. Forest Life Zone Association Tropical Moist

REMARKS *Lower canopy formed by understory palms and small trees.

f. Structural Cell Method:

Stem Dia Class	Stem Dia In	Number of Stems	Total	Sample Cell Dia Ft	Mean Spacing Ft	Stem Density Stems/Acres
1	<1	卌 卌 卌 卌 I	21	20	4.37	2,912
2	1.0	卌 卌 II				
	1.5	卌 卌 I	30	30	0.57	1,787
	2.0	卌 II				
3	2.5	卌 III				
	3.0	卌 II	21	50	10.92	466
	3.5	卌 I				
4	4.0	卌 卌 III				
	4.5	卌 IIII	31	100	17.95	172
	5.0	卌 I				
	5.5	III				
5	6.0	IIII				
	6.5	I	7	100	37.73	39
	7.0	II				
6	7.5	II				
	8.0	I	4	100	50.00	22
	8.5	I				
7	9.0	I	1	100	0.00	0
	9.5					
8	10-15	卌 IIII				
	15.5-30	卌	14	100	23.58	78
	>30					

REMARKS: Trees over 10 inches in diameter: 18, 12, 17, 12, 16, 11, 25, 21, 13, 13, 13, 15, 11, 14

g. Modified Quarter Method:

Sample Number	Stem Spacing, Ft				Stem Diameter In				Stem Height, Ft				Average Stem			
	Quadrant				Quadrant				Quadrant				Spac-ing, Ft	Dia, In	Ht, Ft	Dens-ity stem/acre
	1	2	3	4	1	2	3	4	1	2	3	4				
1	26	4	14	4	5	3.5	2	1	29	22	13	13				
2	4	15	4	7	14	4	2	1	54	30	16	9				
3	4	35	9	6	3	3	4.5	2.5	9	15	23	19				
4	6	11	4	8	19	1.5	3	1	44	11	24	13				
5	21	12	4	14	5	18	3	15	33	28	5	55				
6	3	11	4	5	4.5	6	1	6	23	40	7	48				
7	6	9	14	18	12	5	2	5	48	31	16	42				
8	3	1	3	3	1	1	15	1	8	11	18	12				
9	9	2	13		2	1	6	2	11	14	38	14				
10	4	6	4	2	3	1	1	4	27	13	9	37				

REMARKS:

h. Recognition Distance (12-in Star Target)
Area: Open ________ Forest X

Target Height, Ft	Recognition Distance, Ft					Average Ft
	Target No.					
	1	2	3	4	5	
0	15	15	15	17		15.5
1	20	18	18	18		18.5
5	25	22	33	27		26.75

REMARKS:

PHOTOGRAPHIC DATA

ASA Film Rating BW TRI-X Pan 400 400
Shutter Speed, 1/sec 1/60 Camera Max. Aperture 2.8
f Stop Used 2.8

Roll	Exposure No.	Grid Coordinate	Direction	Description
3	7	42730945	East	Site Overview
	8	42730945	West	Site Overview
	9	42730945	North	Site Overview
	10	42730945	South	Site Overview

APPENDIX C. MAPPING TECHNIQUES FOR SELECTED TERRAIN FACTORS

I. INTRODUCTION

BACKGROUND

Authority for this study was given in response to the US Army Tropic Test Center's request for support as specified in: Letter, STETC-AO, US Army Tropic Test Center, 18 May 1979, subject: Request for Terrain Mapping Support, as described by Letter, ETL-PRO, US Army Engineer Topographic Laboratories, 22 June 1979, subject: US Army Engineer Topographic Laboratories (USAETL) Support to the US Army Tropic Test Center (USATTC) in Panama.

This support involved two individuals, a botanist and a geologist, who conducted a 2-week laboratory and field study to identify and describe selected vegetation, soils, terrain and geological factors as requested by USATTC to establish a data base for the new USATTC environmental test area at Gamboa (figure 1 of basic report).

PURPOSE

Aerial photographic interpretation and analysis techniques were used to establish a resources inventory/selected terrain data base for the area selected for relocating the USATTC test area. This data base permitted:

a. Identification and description of various plant communities by their physiognomic, height and canopy closure characteristics.

b. Description of selected soil conditions associated with the plant communities; soil texture, soil color and parent materiel.

c. Description of selected geological and terrain conditions found within the site, which included: major bedrock types, percent slope, and direction of slope.

II. PROCEDURES

The aerial photography used in this study was 1:20,000 scale panchromatic aerial photography, IV IAGS USAF M-06, USAF 72-27R6 dated 7 and 10 February 1973. Color infrared photography covering the eastern two-thirds of the study area was loaned by the Panama Canal Company and the Agency for International Development, Panama. The scale of this photography was 1:20,000, dated March 1979. Using this imagery and available terrain data, various mapping units were identified for preparing drainage, landform geology, and vegetation maps.

DRAINAGE

All drainageways were delineated on an overlay while viewing the photographs stereoscopically. The analyst also observed the longitudinal and cross-sectional profiles of the valleys and gulleys. By carefully marking out the drainage, two objectives were accomplished:

a. The analyst became familiar with the topographic characteristics of the area.

b. Areas of distinct drainage patterns which correspond to different material types and geologic structures were observed and identified.

LANDFORM

A landform overlay was produced by delineating areas of similar landform. That is, areas that were homogeneous in relief, slope, and profile. By comparing the drainage and landform overlays, areas of different r terial types were delineated and inferences made as to composition and geol. structure. Sites were then selected for field verification. After field c eck any problems in characterizing areas were resolved and the overlay map units were adjusted accordingly.

GEOLOGY

After completing photo analysis of the area, most of the units described by Woodring (1957)* were delineated. However, in the area just west of Gamboa and along Cerro Pelado the photo analysis did not agree exactly with Woodring's boundaries. The area mapped by Woodring as the Las Cascadas member agglomerate and volcanic rock appear on the photos (Unit 2) as distinctly imbedded deposits dipping to the west. This was determined by the drainage character (trellis-like), the asymmetry of the ridges and the formation of flat irons along the apparent dip slope. Investigation of outcrops along the Cerro Pelado road showed an apparent tuffaceous sandstone and hard mudstone. The drainage and ridge patterns extend to the north, well into the areas shown by Woodring as altered basalts and andesites. Further field work is needed in this area to refine boundaries.

There are also areas within the mapped (Unit 3) Bohio formation (Tbo) that do not show the characteristic landform development and drainage pattern used by the analyst for delineation of this unit. The area of small lakes just north of the Chagres Airport and the low NW-SE trending ridge at the head of these lakes appear to be lower in elevation with a more gentle slope than the rest of the area mapped as Bohio formation.

Lineations along this ridge may indicate faulting which could change the surface expression in this area. The area was not field checked and therefore was included in the conglomerate unit (Bohio formation) as shown by Woodring.

---

* Woodring, W.P., Geology and Paleontology of Canal Zone and Adjoining Parts of Panama, Geological Survey Professional Pager 206-A; US Government Printing Office, Washington, 1957.

DESCRIPTION OF GEOLOGY MAP UNITS

The units established to describe the geology of the area are as follows:

Unit 1—Alluvial and fill material—Generally flat areas along the Panama Railroad and banks of the Canal. Much of this material is fill used in building and maintaining the railroad and Canal and is composed of poorly sorted gravels, sands and clays. There are two areas of natural alluvium in the area, along the Chagres River at the east end of the area and near the mouth of the Frijoles River in the western portion.

Unit 2—Tilted, coarse-grained bedded rocks--Predominates on the western face and to the north of Cerro Pelado. These tuffaceous sandstone agglomerate and mudstone dip to the west forming asymmetrical ridges with typical flat-iron topography formed on the dip slope. The drainage is angular to trellis, being controlled by the bedding. This unit forms high hills with sharp crests with the east face being steeper than the west.

Unit 3—Boulder conglomerate--A weakly cemented conglomerate made up of sand, silts and basaltic boulders. This forms an area of hills with a dendritic drainage pattern. This unit is predominately west of Gamboa.

Unit 4—Intrusive igneous rocks--These are basaltic dikes intruded into the conglomerate. They form very steep sided ridges that, being more resistant, rise above the surrounding hills. Basaltic blocks and outcrops are present at the surface. This unit produces the steepest slopes encountered in the field.

Unit 5—Undifferentiated igneous rocks--Altered basalts and andesites forming steeply rounded hills.

Unit 6—Flat lying or gently dipping sedimentary rock-shale, sandstone, and mudstones forming rolling lowlands—the low area in the Frijoles River Basin is formed on these softer sediments. Drainage is dendritic with small flood plains formed along major streams.

VEGETATION

The aerial photography permitted the identification of forest, shrub and grass/herbaceous lands. Trees were defined as woody stemmed plants greater than 16 feet (5 m) in height and +0.6 inches (+2 cm) diameter at breast height (DBH); shrubs were woody stemmed plants less than 16 feet (5 m) in height and with multiple stems, and grasses/ herbaceous plants were nonwoody plants usually less than 3 feet (1 m) in height. The tall, 16 to 26 feet (5 to 8 m) cane-like grasses and herbaceous Heliconia and Catalea species were included in the grassland classification.

The majority of the new test area was forested in which several sub-units were identified using tree height, and percent canopy/closure cover of the dominant or upper tree canopy. Significance was given to the height class having the greatest percent closure. The tallest tree class having +25 percent canopy closure was assigned the greatest importance and used to describe the plant community and the map symbol. The various height and cover classes and the corresponding mapping symbols and criteria were:

Map Symbol	Height Class	Cover Class
1	Short - less than 52 to 63 ft (less than 15 to 20 m)	Less than 30% cover
2	Medium - 64 to 98 ft (20 to 30 m)	30-60% cover
3	Tall - greater than 98 ft (greater than 30 m)	61-90% cover
4	greater than 90% cover	

The mapping units and their descriptions are in table C-1. No attempt was made to characterize the species composition of the various mapping units, because it was nearly impossible from the scale of photography used. The minimum size mapping unit was about 6 acres (2 hectares).

The size of the tree canopies was determined from aerial photography for each of the mapping units. The tree heights, crown diameters and stem DBH of 4.5 foot (1.4 m) of selected trees were determined during the field reconnaissance. Detailed data describing vegetation structural characteristics at selected sample sites were collected by USATTC in the test area. The data were used as appropriate.

Table C-1. Land Cover Mapping Units For Gamboa Test Study Area

Physiognomic Unit	Map Symbol	Description
	General Categories:	
Grasslands	100	Grass lands; primarily Panacum maximum, other cane-like grasses and herbaceous species.
Shrublands	200	Shrublands; woody stemmed plants less than 15 feet (5 m) tall and less than 1 inch (2 cm) DBH.

Table C-1 (concluded)

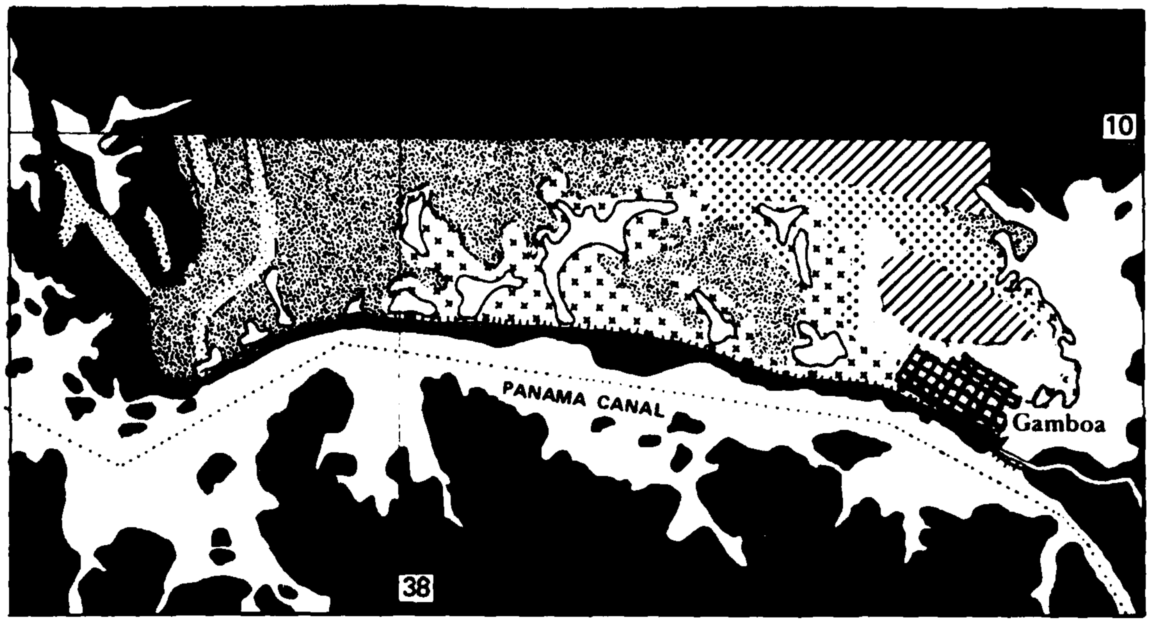
Physiognomic Unit	Map Symbol	Description
		General Categories:
Forest Lands	300	Woody stemmed plants more than 5 m tall and greater than 2 cm DBH.
Water Bodies	500	Lakes and rivers.
Wet Lands	600	Areas found between water and uplands that are inundated for most of the year.
Urban/Built-Up Areas	900	Areas of a high concentration of human activity, i.e., residential, commercial, industrial areas.
		Forest Categories:
Short	312	Trees 15 to 60 feet (5 to 20 m) tall, 30-60% canopy closure.
	313	Trees 5 to 20 m tall, 60-90% canopy closure.
Medium	321	Trees 60 to 100 feet (20 to 30 m) tall and less than 30% canopy closure.
	322	Trees 20 to 30 m tall and 30-60% canopy closure.
	323	Trees 20 to 30 m tall, and 60-90% canopy closure.
Tall	331	Trees more than 30 m tall and less than 30% canopy closure.
	332	Trees more than 30 m tall and 30-60% canopy closure.
	333	Trees more than 30 m tall and 60-90% canopy closure.

Because of the limited time alotted for field work, no attempt was made to identify all species within the various mapping units; at best only the more common species were identified.

III. RESULTS

GEOLOGY

Woodring described seven major rock and substrata types found in the study area (figure C-1), most of which are of igneous or depositional origin. Altered basaltic and andesitic volcanic rocks and tuff unit (KV), which includes diorite and dacite, intrusive rocks; and the Gatuncillo (Tgo) sedimentary rock formation which includes mudstones, siltstones, and limestones occur along the northern border of the test area. This KV unit forms the mountains/hills in the north, west and east portions of the study area. The elevations in these areas range from 200 to 230 meters and may reach 240 meters.



LEGEND: (after W. P. Woodring, 1957)
Kv Alter basaltic and andesitic volcanic rocks and tuff
Tgo Gatuncillo formation
Tlc Las Cascadas
Tbo Bohio formation
Tb Intrusive and extrusive basalts
Tc Undifferentiated, Calamitio formation
Qma Marine deposits, alluvium, artificial fill

Figure C-1. Geological Map of the Test Area.

The Tgo unit forms the Rio Frijoles Basin, and the western and southern flanks of the KV unit along the western edge of the test area. This unit also comprises the mid-slopes of small hills lying between the Panama Railroad and the uplands areas.

The Bohio formation (Tbo), consisting of conglomorate and sandstone, forms the lower elevation hills that lie between the Canal and the Frijoles River Basin.

The Intrusive and Extrusive basalts (Tb) are found along the western edge of the study area generally as discontinuous ridges just east of the railroad tracks and as small islands in Gatun Lake on the western slope of the study area.

The undifferentiated Calamitio formation, (Tc), consisting of tuffaceous siltstone, tuffaceous sandstone, tuff, conglomerate, and limestone, forms the low-lying areas on the western edge of the study area, generally between and along the railroad tracks and the Rio Frijoles.

The Las Cascadas agglomerate (Tcl), consisting of agglomerate and tuff, is a small unit at Gamboa and the immediate surrounding upland areas, and is localized distribution.

The marine deposits, alluvium, artificial fill (Qma), containing silts, sand, and gravels are found along the southern edge of the test area and adjacent to the Canal. These areas are flat-lying and include several small lakes, an air strip, and the railroad bed. This unit contains fill from the construction of the Canal and subsequent maintenance dredging.

LAND COVER

Land cover in the test area was characterized by the physiognomic characteristics of the vegetation: trees, shrubs and grass/herbaceous; and by the urban/commercial and surface water bodies. Areas composed primarily of shrubs or grass species were not further subdivided beyond this initial "break out," because these land-cover units were generally small and too difficult to map at a scale of 1:10,000. Also the data needed to verify their characters required substantial ground truth data. The forest lands were the major land cover unit within the study area. Forested areas were characterized by differences in the height and percent canopy closure of the forest cover, from information acquired from the stereoscopic view aerial photography. The mapping symbols and definitions of each mapping unit are shown in table C-1, above.

Most grassland areas were found along the Panama Railroad right-of-way, on fill material, the hills along the southern margins of the test areas, and along the pipeline and Pipeline Road. Several small upland grasslands were present in the western areas and on some hills near the Pipeline Road. These grass areas are maintained for viewing the Canal navigation markers placed on upland areas. The grass cover in the marshlands was dense, with stem diameters ranging from 40 to 60 stems per-square-yard, and was 10 to 15 feet (3 to 5 m) tall. Some grass-dominated wetlands were established on and along the Canal and in the margins of lakes.

Shrub species were not usually found over areas large enough to be mapped. The largest shrubland areas were found between the Darien and Frijoles Railroad stops. Here, sizeable upland areas had been cleared of their forest cover for agricultural purposes, corn and banana culture. These sites are now either abandoned or poorly maintained; in either case, tree samplings that were less than 15 feet (5 m) are now being reestablished in these areas.

FORESTED LANDS

Most of the area comprises tropical moist rain forest, species which form two-story tree canopy. The percent ground cover of the forest floor is 100 percent with tree canopy ranging from 75 to 100 percent canopy closure in the two-story canopy. Ground reconnaissance of several forest mapping units revealed considerable diversity in the percent ground cover of the less than 30 feet vegetation strata.

The major species were semi-woody stemmed species, two of which were Panicum maximum and P. giganta. Another grass specie (unknown) was observed which was 3 to 12 feet (1 to 4 m) tall, had a large plumed paniculated influrence and was found primarily in wet areas. P. maximum and the tall plummed grass species were found on upland cleared areas, commonly associated with the navigation markers or on steep slopes. They were also found in wetland areas on slightly higher micro-relief just above the continuously inundated wetland communities. P. giganta was found primarily on saturated soil.

The shortest forest type, map unit 312 and 313, was 15 to 60 feet (5 to 20 m) tall. This forest type was found on upland slopes, in the western end of the test area and in the upland west of Cerro Pelado, and south to Juan Grande Creek. This forest unit had a canopy cover of 60 to 90 percent, and a dense understory which made field survey difficult.

Most of the forests covered in the test area were of medium height, 60 to 90 feet (20 to 30 m) with 30 to 50 (10 to 16.5 m) diameter crowns, map unit 322. This forest type was found south of the MTP 10-grid-line and west of the Calamito Lake. A more dense canopy, 60 to 90 percent in the medium height forest, was observed on higher elevations between Cerro Pelado and Rio Chagres.

Tall trees had variable size crowns of 50 to 150 feet (10 to 50 m) and DBH of 20 to 48 inches (50 to 127 cm). Measurements of an Enterlobium species near sample site 23, had crown diameter of 155 feet (50 m). A Ceibo tree at sample site 19 had a DBH of 4.5 feet (1.3 m). Much of the medium-sized height forest contained some tall trees which were few in number, but generally comprised less than 10 percent of the tree canopy of the mapping unit. Where large trees comprised 10 to 30 percent of the overstory cover, these were indicated as a separate mapping unit 332/331.

The tallest forested areas which also had the largest tree crowns were found along the Rio Frijoles and its major tributaries, in upland isolated areas on steep east facing slopes (60°) and in the uplands just north of the study area, above the 10-grid-line. Generally, the tall forested areas had the least undergrowth, medium height forests an intermediate amount, and the short forest the most undergrowth. This gradient in the density of the undergrowth suggests a successional sequence in the maturation of the forest, with the tallest and oldest forest having the least ground cover. The composition of understory contained a large number of palm species, Meliconia and Calthlea, and seedlings of shade tolerant overstory species.

RECOMMENDATIONS

Future investigations should:

a. Develop a method for predicting soil texture-parent material relations from landform components identified from aerial photography.

b. Conduct a geobotanical study to investigate the distribution of plant communities as affected by species phenology, soil-plantwater relationships and geological and terrain factors, and evaluate those relationships suitable for making predictions in tropical environments using remote sensing techniques.

c. Conduct soil moisture studies for the various soil-landform conditions present in the study area and evaluate existing models for predicting soil moisture using soil textural data.

d. Evaluate existing models describing relationships between (1) stem diameter and tree height, (2) crown diameter and tree height, and (3) crown diameter and stem diameter, for tropic-moist forest.

APPENDIX D. DATA COLLECTED

TABLE D-1. SUMMARY OF SITE DESCRIPTION DATA

Site No.	Grid Coordinates	Elev (ft)	Local Relief (ft)	Parent Material	Landform	Topography: Position*	Topography: Slope (%)	Topography: Drainage: Surface	Topography: Drainage: Internal	Vegetation	Landuse
1	43250905	114	450	Alluvium	Terrace	LS	2.0	Fair	Fair	Grass	None
2	43080911	130	434	Alluvium	Terrace	LS	1.0	Fair	Fair	Forest	Forest
3	43150948	98	466	Alluvium	Terrace	LS	50.0	Excellent	Excellent	Forest	Forest
4	42900941	98	466	Igneous rock	Terrace	LS	2.0	Fair	Fair	Forest	Forest
5	42960921	146	418	Igneous rock	Terrace	LS	9.0	Fair	Fair	Forest	Forest
6	43020925	114	450	Alluvium	Terrace	LS	10.0	Fair	Fair	Forest	Forest
7	42960908	146	418	Igneous rock	Terrace	LS	13.0	Fair	Fair	Forest	Forest
8	43390932	72	388	Alluvium	Terrace	LS	13.5	Fair	Fair	Forest	Forest
9	43100884	260	200	Igneous rock	Intermediate hills	MS	64.0	Excellent	Excellent	Forest	Forest
10	43290949	260	200	Alluvium	Intermediate hills	MS	50.0	Excellent	Excellent	Forest	Forest
11	43260944	228	232	Igneous rock	Intermediate hills	MS	28.0	Good	Good	Forest	Forest
12	42730945	170	290	Igneous rock	Intermediate hills	MS	24.0	Good	Good	Forest	Forest
13	42650956	260	362	Igneous rock	Intermediate hills	US	50.0	Excellent	Excellent	Forest	Forest
14	43010932	98	199	Alluvium	Bottomland	BF	1.0	Poor	Poor	Tree/grass	None
15	42850966	163	377	Igneous rock	Intermediate hills	MS	18.0	Good	Good	Forest	Forest
16	42800917	146	409	Igneous rock	Terrace	BF	12.0	Good	Good	Forest	Forest
17	43450920	114	373	Alluvium	Terrace	BF	1.0	Fair	Fair	Grass	None
18	42560972	150	158	Agglomerate	Intermediate hills	MS	70.0	Excellent	Excellent	Forest	Forest
19	43050975	98	285	Alluvium	Bottomland	BF	4.0	Poor	Poor	Grass	None
20	40970916	205	178	Conglomerate	Intermediate hills	MS	18.0	Good	Good	Forest	Forest
21	39330918	114	269	Conglomerate	Low hills	LS	18.0	Good	Good	Forest	Forest
22	39400913	98	285	Conglomerate	Low hills	LS	22.0	Good	Good	Forest	Forest
23	39650870	62	321	Conglomerate	Terrace	LS	18.0	Good	Good	Forest	Forest
24	37700857	91	495	Alluvium	Manmade lowlands	BF	1.0	Fair	Fair	Grass	None
25	35450810	169	417	Conglomerate	Intermediate hills	MS	10.0	Fair	Fair	Forest	Forest
26	36350870	166	420	Conglomerate	Intermediate hills	MS	40.0	Good	Good	Forest	Forest
27	41250897	169	417	Alluvium	Intermediate hills	MS	35.0	Good	Good	Forest	Forest
28	40320852	114	472	Conglomerate	Low hills	US	15.0	Fair	Fair	Tree/grass	Forest
29	42260908	244	342	Agglomerate	Intermediate hills	MS	35.0	Good	Good	Forest	Forest
30	40480985	148	235	Sedimentary rock	Low hills	LS	26.0	Good	Good	Forest	Forest
31	40580937	205	178	Conglomerate	Low hills	US	25.0	Good	Good	Forest	Forest

* LS--Lower slope
MS--Middle slope
US--Upper slope
BF--Bottomland flat

TABLE D-2. SUMMARY OF

Date 1979	Site No.	Grid Coordinates	Soil Classification 0-6 in USDA	Soil Classification 0-6 in USCS	Soil Classification 6-12 in USDA	Soil Classification 6-12 in USCS	SFC	Average Cone Index 3	6	9	12	15	18	0-6	6-12	12-18	Remolding Index 0-6	Remolding Index 6-12	Rating Cone Index 0-6	Rating Cone Index 6-12
								At Depth in Inches												
6-20	1	43250905	Clay	MH	Clay	MH	55	120	126	146	154	252	214^{+}	100	142	224	0.70	0.77	70	109
6-20	2	43080911	Clay	MH	Clay	MH	48	110	142	172	246	282	305	100	187	278	1.00	1.00	100	187
6-21	3	43150940	Clay	MH	Clay	MH	12	26	42	46	62	54	58	27	50	58	0.69	1.00	18	50
6-21	4	42900941	Clay	MH	Clay	MH	17	43	72	89	107	100	101	44	89	103	0.64	0.81	28	72
6-22	5	42960921	Clay	MH	Clay	MH	52	111	156	192	230	248	281.5	106	193	253	1.00	1.00	106	193
6-22	6	43020925	Clay	MH	Clay	MH	39	93	110	132	174	270^{+}	285^{+}	87	139	243^{+}	0.86	1.00	70	139
6-25	7	42960908	Clay	MH	Clay	MH	43	91	129	158	182	210	227	88	156	206	1.00	1.00	88	156
6-26	8	43390932	Clay	MH	Clay	MH	44	88	133	166	219	352	344^{+}	88	173	305^{+}	0.91	1.00	80	173
6-26	9	43100884	Clay	MH	Clay	MH	42	94	127	126	125	141	152^{+}	87	126	139^{+}	1.00	1.00	87	126
6-27	10	43290949	Clay	MH	Clay	MH	48	106	272	387^{+}	516^{+}	684^{+}	687^{+}	142	392^{+}	629^{+}	1.00	1.00	142	392^{+}
6-27	11	43260944	Clay	MH	Clay	MH	28	107	118	114	144	266^{+}	345^{+}	84	125	252	1.00	1.00	84	125
6-28	12	42730945	Clay	MH	Clay	MH	62	109	230	322^{+}	411^{+}	511^{+}	593^{+}	134	321^{+}	505^{+}	0.79	1.00	106	321^{+}
6-28	13	42650956	Clay	MH	Clay	MH	47	48	117	127	157	209	273	81	134	213	0.59	1.00	48	134
7-2	14	43010932	Clay	MH	Clay	MH	11	34	57	54	59	80	105	34	57	81	0.51	1.00	17	57
7-2	15	42850966	Clay	MH	Clay	MH	52	140	195	245	306	325	408^{+}	129	249	346^{+}	1.00	1.00	129	249
7-3	16	42800917	Clay	MH	Clay	MH	28	82	108	212^{+}	335^{+}	297^{+}	325^{+}	73	218^{+}	319^{+}	1.00	1.00	73	218^{+}
7-3	17	43450920	Clay	MH	Clay	MH	46	137	255	460^{+}	715^{+}	749^{+}	750^{+}	146	477^{+}	738^{+}	1.00	1.00	146	477^{+}
7-5	18	42560972	Clay	MH	Clay	MH	63	105	195	328	388	422^{+}	529^{+}	121	304	446^{+}	1.00	1.00	121	304
7-5	19	43050975	Clay	MH	Clay	MH	23	66	106	93	117	141	153	65	105	137	0.88	1.00	57	105
7-10	20	40970916	Clay	MH	Clay	MH	43	186	222^{+}	235^{+}	225^{+}	259^{+}	293^{+}	150^{+}	227^{+}	259^{+}	1.00	1.00	150^{+}	227^{+}
7-11	21	39330918	Clay	MH	Clay	MH	62	129	199	245	275	351	412	130	240	346	1.00	1.00	130	240
7-12	22	39400913	Clay	MH	Clay	MH	54	122	131	178	167	158	191	102	159	108	0.99	1.00	101	159
7-12	23	39650870	Clay	MH	Clay	MH	42	83	123	147	176	222	314^{+}	83	149	237^{+}	1.00	1.00	83	149
7-12	24	37700857	Clay	MH	Clay	MH	36	122	188	323^{+}	389^{+}	466^{+}	655^{+}	115	300	503	1.00	1.00	115	300^{+}
7-13	25	35450810	Clay	MH	Clay	MH	42	75	123	150	178	216	317	80	150	237	1.00	1.00	80	150
7-13	26	36350870	Clay	MH	Clay	MH	34	69	84	167^{+}	189^{+}	232^{+}	254^{+}	62	147^{+}	225^{+}	1.00	1.00	63	147
7-16	27	41250897	Clay	MH	Clay	MH	21	65	99	109	116	143	153	62	108	137	1.00	1.00	62	108
7-17	28	40320852	Clay	MH	Clay	MH	43	80	220	255^{+}	300^{+}	354^{+}	358^{+}	114	258	337	0.83	1.00	95^{+}	258^{+}
7-17	29	42260908	Clay	MH	Clay	MH	75	201	260	350^{+}	433^{+}	459^{+}	584^{+}	179	348^{+}	492^{+}	1.00	1.00	174	348
7-18	30	40480985	Clay	MH	Clay	MH	52	107	143	162	160	194	216	101	155	190	1.00	1.00	101	155
7-18	31	40580937	Clay	MH	Clay	MH	57	110	133	150	144	284^{+}	287^{+}	100	142	238^{+}	0.82	1.00	82	142

SURFACE COMPOSITION DATA

Sheargraph at Surface Natural Wetness				SFC Free Water				Moisture Content Depth in Inches				Density Depth in Inches				Soil	Water
Cl	Cr	ϕl	ϕr	Cl	Cr	ϕl	ϕr	0-3	3-6	6-9	9-12	0-3	3-6	6-9	9-12	Depth	Table
(lb/in^2)	(lb/in^2)	(deg)	(deg)	(lb/in^2)	(lb/in^2)	(deg)	(deg)	(%)				(lb/cu. ft)				(in)	(in)
1.1	0.5	15.2	15.3	1.1	0.5	15.2	13.7	59.5	49.7	—	—	61.3	73.1	—	—	f24	f24
0.8	0.6	12.0	11.6	1.8	1.3	9.0	9.0	68.1	65.3	—	—	56.1	46.8	—	—	f24	f24
1.2	0.3	28.5	29.0	0.1	0.0	26.4	24.5	59.8	44.1	39.2	—	55.1	74.2	68.6	—	f24	f24
1.0	0.4	11.5	12.7	1.2	0.6	19.6	18.4	72.7	64.4	—	—	53.7	62.8	—	—	f24	f12
1.4	0.5	19.5	19.5	0.8	0.1	23.0	21.7	57.2	—	—	—	61.0	—	—	—	f24	f24
1.2	0.7	20.0	18.6	0.4	0.0	15.0	13.0	58.7	45.6	—	—	60.4	69.0	—	—	f24	f12
0.8	0.3	21.6	19.7	0.6	0.1	20.5	17.5	73.2	57.6	—	—	52.2	61.9	—	—	f24	f24
0.8	0.3	25.7	24.3	0.2	0.0	24.0	20.6	71.7	62.1	58.7	52.3	50.9	59.3	62.9	66.6	f24	f24
2.6	2.1	25.5	24.0	0.4	1.9	11.0	9.5	57.2	53.2	—	—	54.1	60.5	—	—	f24	f24
0.6	0.1	21.0	19.3	0.2	0.0	21.5	18.0	36.3	2.4	27.2	—	66.2	90.7	78.8	—	f24	f24
0.2	0.0	31.5	27.0	0.2	0.0	23.0	19.7	63.0	50.0	43.0	—	56.8	65.7	71.4	69.8	f24	f24
0.5	0.1	31.2	19.6	0.1	0.0	28.0	24.2	43.3	32.2	33.0	—	72.0	86.2	85.8	—	f24	f24
0.8	0.3	28.0	24.4	0.9	0.4	19.0	164.4	66.8	69.5	67.6	63.6	67.7	66.6	66.3	57.3	f24	f24
0.2	0.0	25.5	22.5	0.2	0.0	24.0	20.6	78.0	—	—	—	51.8	—	—	—	f24	f24
0.5	0.1	24.5	22.0	0.8	0.4	27.0	23.3	49.3	51.1	59.2	66.3	73.4	76.3	65.5	75.6	f24	f24
1.3	0.7	21.6	19.4	0.4	0.0	14.5	12.3	—	67.0	—	—	—	—	—	—	f24	f24
1.2	0.6	26.0	23.0	0.2	0.7	28.0	24.1	—	—	—	—	—	—	—	—	f24	f24
0.0	0.0	29.0	25.0	1.2	1.8	24.0	20.2	69.6	54.8	—	—	55.7	54.3	—	—	f24	f24
1.3	0.5	10.0	11.4	2.3	0.0	3.0	2.3	103.3	67.2	58.8	56.7	60.8	56.5	59.6	64.1	f24	f24
1.8	1.3	19.5	18.4	0.1	1.8	16.0	14.6	—	—	—	—	—	—	—	—	f24	f24
3.8	3.6	21.5	19.0	2.2	0.8	23.5	23.0	—	—	—	—	—	—	—	—	f24	f24
1.0	0.8	28.5	23.0	1.1	0.6	18.0	16.0	—	—	—	—	—	—	—	—	f24	f24
3.0	2.0	15.5	15.5	1.0	0.6	20.5	18.5	—	—	—	—	—	—	—	—	f24	f24
2.0	1.0	27.0	26.0	0.8	0.6	22.5	20.5	49.3	18.5	—	—	65.1	84.7	—	—	f24	f24
1.8	1.0	16.0	17.3	1.3	1.3	14.7	11.4	45.0	43.0	—	—	100.7	80.3	—	—	f24	f24
2.5	2.2	24.5	22.0	1.2	1.2	21.0	18.0	61.2	45.2	32.0	31.5	96.2	108.2	108.4	94.0	f24	f24
—	—	—	—	—	—	—	—	60.5	41.7	30.3	—	59.1	78.9	99.9	—	f24	f24
1.9	0.6	24.0	25.0	0.9	0.7	20.0	16.0	23.7	38.1	23.3	—	88.8	77.2	81.7	—	f24	f24
2.2	1.8	8.5	8.5	1.0	0.8	11.0	8.5	28.7	25.9	25.3	—	89.9	98.4	96.2	—	f24	f24
2.1	1.7	21.5	21.0	3.1	2.3	10.5	8.0	78.3	44.0	—	—	49.9	80.5	—	—	f24	f24
2.0	1.6	12.5	10.0	1.4	1.0	21.0	16.0	55.9	46.8	48.7	48.5	64.9	75.6	57.5	/0.00	f24	f24

TABLE D-3. SUMMARY OF SURFACE GEOMETRY DATA

Date 1979	Site No.	Grid Coordinates	MICROGEOMETRY Std. Dev.	RMS a/	OBSTACLES Direction b/	Station No.	Distance (ft)	Type	Shape c/	Length (in)	Width (in)	Height (in)	Axis Az. (deg)	Approach Angle (deg)
6-20	1	43250905	—	—	—	—	—	—	—	—	—	—	—	—
6-20	2	43080911	7.54	0.8	—	—	—	—	—	—	—	—	—	—
6-21	3	43150948	14.35	1.6	—	—	—	—	—	—	—	—	—	—
6-21	4	42900941	—	1.3	—	—	—	—	—	—	—	—	—	—
6-22	5	42960921	3.15	0.8	left	0+0	2	stump	R	—	12	36	—	90
			—	—	left	0+1	20	stump	R	—	60	48	—	90
			—	—	right	0+10	30	stump	R	—	18	60	—	90
			—	—	left	0+20	30	stump	R	—	12	24	—	90
			—	—	left	0+20	30	stump	R	—	24	36	—	90
			—	—	right	0+20	20	stump	R	—	24	48	—	90
			—	—	left	0+30	30	stump	R	—	18	24	—	90
			—	—	left	0+40	15	stump	R	—	12	18	—	90
			—	—	left	0+40	25	stump	R	—	12	24	—	90
			—	—	left	0+60	40	log	C	60	12	—	—	90
			—	—	left	0+90	17	stump	R	—	24	36	—	90
			—	—	right	0+100	3	log	C	180	48	—	—	90
			—	—	left	0+100	15	stump	R	—	60	12	—	90
6-22	6	43020925	14.15	1.0	left	0+0	3	stump	R	—	4	12	—	90
			—	—	left	0+0	10	rock	O	60	54	24	—	45
			—	—	left	0+0	11	rock	O	120	96	60	—	75
			—	—	right	0+0	18	log	C	240	12	—	—	90
			—	—	left	0+10	15	log	C	240	48	—	—	90
			—	—	right	0+10	40	log	C	240	12	—	—	90
			—	—	left	0+20	15	rock	O	24	18	12	—	75
			—	—	left	0+20	17	rock	O	24	18	10	—	80
			—	—	left	0+20	19	stump	R	—	4	18	—	90
			—	—	right	0+20	17	log	C	240	7	—	—	90
			—	—	right	0+20	15	log	C	60	7	—	—	90
			—	—	right	0+20	14	log	C	300	3	—	—	90
			—	—	left	0+30	35	rock	O	84	60	48	—	45
			—	—	right	0+30	20	rock	O	42	36	36	—	60
			—	—	left	0+40	35	rock	O	24	8	6	—	80
			—	—	left	0+40	35	rock	O	24	8	12	—	60
			—	—	right	0+40	22	log	C	36	8	—	—	90
			—	—	right	0+40	22	log	C	48	5	—	—	90
			—	—	left	0+40	40	rock	O	24	36	12	—	60
			—	—	left	0+40	40	rock	O	30	12	18	—	75
			—	—	left	0+50	4	rock	O	48	12	12	—	45
			—	—	left	0+50	20	rock	O	18	12	12	—	40
			—	—	left	0+50	16	rock	O	36	12	18	—	60
			—	—	right	0+50	22	rock	O	18	18	12	—	75
			—	—	left	0+60	35	stump	R	—	36	18	—	90
			—	—	left	0+60	40	log	C	360	18	18	—	90
			—	—	left	0+90	20	stump	R	—	18	36	—	90
			—	—	left	0+100	6	stump	R	—	24	30	—	90

6-25	7	42960908	8.38	1.1	right	0+6	0	log	C	300	4	—	—	90
			—	—	left	0+20	3	stump	R	—	30	48	—	90
			—	—	left	0+23	25	log	C	48	5	—	—	90
			—	—	right	0+30	0	stump	R	—	9	12	—	90
			—	—	left	0+35	30	log	C	12	6	—	—	90
			—	—	right	0+36	30	log	C	4	5	—	—	90
			—	—	right	0+57	4	stump	R	—	12	24	—	90
			—	—	right	0+61	25	stump	R	—	12	24	—	90
			—	—	right	0+70	5	rock	R	28	18	6	—	70
			—	—	right	0+72	12	stump	R	—	10	18	—	90
			—	—	right	0+73	9	rock	O	32	15	6	—	90
			—	—	right	0+73	10	log	C	60	6	—	—	90
			—	—	right	0+73	12	log	C	72	5	—	—	90
			—	—	right	0+74	20	stump	R	18	10	15	—	90
			—	—	left	0+75	15	log	C	60	4	—	—	90
			—	—	left	0+75	15	log	C	144	4	—	—	90
			—	—	right	0+75	18	stump	R	—	4	15	—	90
			—	—	right	0+80	18	stump	R	—	15	22	—	90
			—	—	right	0+91	0	stump	R	—	9	17	—	90
6-26	8	43390932	2.51	1.1	left	0+0	12	log	C	300	3	—	—	90
			—	—	left	0+3	2	log	C	420	6	—	—	90
			—	—	right	0+30	10	log	C	360	5	—	—	60
			—	—	left	0+40	0	log	C	240	5	—	—	90
			—	—	left	0+89	0	log	C	420	12	—	—	90
			—	—	right	0+100	2	log	C	480	9	—	—	90
6-26	9	43100884	9.46	2.9	right	0+2	50	log	C	180	7	—	—	90
			—	—	right	0+36	43	log	C	180	2	—	—	90
			—	—	left	0+100	0	log	C	240	7	—	—	90
6-27	10	43290949	8.65	1.7	right	0+20	18	log	C	360	10	—	—	90
			—	—	left	0+59	15	log	C	180	96	—	—	90
			—	—	right	0+60	10	log	C	144	96	—	—	90
			—	—	left	0+63	20	log	C	120	72	—	—	90
6-27	11	43260944	18.76	2.1	right	0+5	20	rock	O	24	36	6	—	90
			—	—	right	0+20	20	rock	O	36	24	12	—	90
			—	—	right	0+50	5	log	C	192	4	—	—	90
			—	—	right	0+60	15	log	C	300	4	—	—	90
			—	—	right	0+70	44	log	C	96	5	—	—	90
6-28	12	42730945	1.83	1.1	left	0+20	20	log	C	360	9	—	—	90
			—	—	left	0+80	10	log	C	540	24	—	—	90

a/ Data Detrended using a USAWES program

b/ Left or right of Principal Axis

c/ R - Round
C - Cylinder
O - Oblong

Table D-3 (concluded)

Date 1979	Site No.	Grid Coordinates	MICROGEOMETRY Std. Dev.	RMS a/	OBSTACLES Direction b/	Station No.	Distance (ft)	Type	Shape c/	Length (in)	Width (in)	Height (in)	Axis Az. (deg)	Approach Angle (deg)
			—	—	left	0+90	40	log	C	300	5	—	—	90
			—	—	right	0+90	30	log	C	120	18	—	—	90
			—	—	right	0+95	20	log	C	480	10	—	—	90
			—	—	right	0+100	15	log	C	120	12	—	—	90
6-28	13	42650956	5.77	2.61	left	0+50	20	log	C	960	13	—	—	90
7-02	14	43010932	4.71	2.44	left	0+49	13	log	C	360	4	—	—	90
			—	—	left	0+50	27	rock	C	48	36	—	—	90
					STREAM GOES THROUGH ENTIRE SITE									
7-02	15	42850966	4.63	0.19	—	0+40	—	root	R	40	12	12	—	90
7-03	16	42800917	11.26	1.31	left	0+40	20	log	C	432	7	—	—	75
			—	—	left	0+80	35	log	C	456	6	—	—	90
			—	—	left	0+85	15	log	C	108	10	—	—	0
7-03	17	43450920	8.47	0.87	right	0+82	6	stump	R	—	4	—	—	90
					STATION 92-100 IS SWAMP									
7-05	18	42560972	4.65	1.94	left	0+76	40	stump	R	—	24	24	—	90
					VINES COVER ENTIRE SITE									
7-05	19	43050975	7.02	2.90	left	0+50	1	log	C	168	8	—	—	90
			—	—	left	0+52	2	log	C	180	7	—	—	90
7-10	20	40970916	15.89	2.31	—	—	—	—	-	—	—	—	—	—
7-11	21	39330918	11.89	2.11	right	0+0	10	rock	O	60	36	2.5	—	90
			—	—	left	0+1	0	rock	O	24	36	24	—	90
			—	—	left	0+24	10	rock	O	2	36	12	—	90
			—	—	left	0+73	10	log	C	240	8	—	—	90
			—	—	left	0+49	13	rock	O	14	14	6	—	40
			—	—	left	0+50	13	log	C	72	4	—	—	90
			—	—	left	0+53	6	log	C	84	5	—	—	90
			—	—	right	0+55	14	log	C	96	12	—	—	90
			—	—	right	0+57	22	stump	R	—	96	30	—	90
			—	—	left	0+58	27	log	C	144	5	—	—	90
			—	—	left	0+60	0	log	C	264	72	—	—	90
			—	—	left	0+83	20	log	O	12	18	—	—	60
			—	—	right	0+100	40	log	C	600	6	—	—	60
7-12	22	39400913	—	—	left	0+3	26	stump	R	—	6	42	—	90
			—	—	right	0+97	1	log	C	216	48	—	—	90
			—	—	right	0+98	15	log	C	288	60	—	—	90
			—	—	right	0+99	0	log	C	240	78	—	—	90
7-12	23	39650870	4.16	2.10	left	0+85	25	rock	O	12	12	12	—	80
7-12	24	37700857	—	3.66	—	—	—	—	-	—	—	—	—	—
7-13	25	35450810	14.26	—	left	0+0	2	log	C	240	60	—	—	90
			—	—	left	0+15	25	log	C	150	4	—	—	90
			—	—	right	0+50	33	rocks	R	144	24	12	—	90
			—	—	right	0+70	13	log	C	150	6	—	—	90
7-13	26	36350870	35.0	—	left	0+0	0	ditch	V	1200	72	60	250	90
			—	—	left	0+3	4	rock	O	8	8	5	—	60
			—	—	right	0+70	12	rock	O	24	12	12	—	65

7-16	27	41250897	5.57	2.88	left	0+0	0	log	C	60	6	6	--	90
			—	—	left	0+10	0	log	C	84	4	12	—	90
			—	—	right	0+14	1	log	C	180	4	4	--	90
			—	—	right	0+15	12	log	C	180	3	3	--	90
			—	—	right	0+25	25	stump	R	—	12	12	0	90
			—	—	left	0+30	25	log	C	240	4	—	120	90
7-17	28	40320852	6.30	1.88	—	—	—	—	-	--	--	—	--	--
7-17	29	42260908	5.80	2.71	—	—	—	—	-	—	—	—	--	--
7-18	30	40480985	—	—	right	0+27	—	log	C	144	6	—	100	90
			—	—	left	0+30	—	log	C	144	8	—	170	90
			—	—	right	0+31	—	log	C	216	6	—	75	90
7-18	31	40580937	18.49	4.16	LARGE VINES THROUGHOUT ENTIRE SITE									

a/ Data Detrending using a USAWES program

b/ Left or right of Principal Axis

c/ R - Round
C - Cylinder
O - Oblong

TABLE D-5. SUMMARY OF VEGETATION DATA - MODIFIED QUARTER METHOD

Date 1979	Site No	Grid Coordinates	Stem Dia Class No a/	Cell Dia	No of Stems	Stem b/ Density	Total Stems <1 in	Total Stems >1 in	Stem Class Spacing	Cum Stem Number for Diams ≤	Cum Stem Number for Diams ≥	Stem Spacing, Ft, for Dia Classes ≤	Stem Spacing, ft, for Dia Classes ≥	Average Recognition Distance for Target Heights 0	1	5	Light Intensity
				(ft)					(ft)						(ft)		(CD/ft²)
6-20	1	43250905	Grass														
6-20	2	43080911	1	100	500	2,774.0	500		4.47	500	877	4.47	3.38	3.00	3.00	11.00	1.60
			2	100	250	1,384.0			6.33	750	377	3.65	5.13	13.00	22.25	36.50	0.80
			3	100	64	354.0			12.55	814	127	3.50	8.87				
			4	100	33	239.0			17.45	847	63	3.44	12.60				
			5	100	16	491.0		377	25.00	863	30	3.40	18.26				
			6	100	7	39.0			37.74	870	4	3.39	26.73				
			7	100	1	5.5			100.00	871	7	3.39	37.80				
			8	100	6	33.0			40.85	877	6	3.38	40.82				
6-21	3	43150940	1	100	525	2,913.0	525		4.37	525	805	4.36	3.52	10.75	16.50	25.00	0.80
			2	100	125	692.0			8.95	650	280	3.92	5.98				
			3	100	106	588.0			9.71	756	155	3.64	8.03				
			4	100	25	139.0			20.00	781	49	3.57	14.29				
			5	100	3	17.0		280	57.80	784	24	3.57	20.41				
			6	100	7	39.0			37.73	791	21	3.55	21.82				
			7	100	1	6.0			100.00	792	14	3.55	26.73				
			8	100	13	72.0			27.70	805	13	3.52	27.74				
6-21	4	42900941	1	100	125	693.0	125		8.95	125	223	8.94	6.70	12.50	31.25	43.75	3.20
			2	100	64	354.0			12.50	189	98	7.27	10.10				
			3	100	8	44.0			35.34	197	34	7.12	17.15				
			4	100	6	33.0			40.81	203	26	7.02	19.61				
			5	100	1	5.0		98	100.00	204	20	7.00	22.36				
			6	100	2	11.0			70.92	206	19	6.97	22.94				
			7	100	0	0.0			0	206	17	6.97	24.25				
			8	100	17	61.0			24.27	223	17	6.70	24.25				
6-22	5	42960921	1	100	675	3,745.0	675		3.85	675	953	3.85	3.24	21.50	39.50	46.25	3.20
			2	100	163	900.0			7.86	838	278	3.45	6.00				
			3	100	69	385.0			12.00	907	115	3.32	9.33				
			4	100	8	44.0			35.33	915	46	3.30	14.74				
			5	100	8	44.0		278	35.33	923	38	3.77	16.22				
			6	100	2	11.0			70.92	925	30	3.29	18.26				
			7	100	6	33.0			40.82	931	28	3.27	18.90				
			8	100	22	122.0			21.32	953	22	3.23	21.23				
6-22	6	43020925	1	100	550	3,051.0	550		4.26	550	844	4.26	3.44	24.00	40.75	53.25	0.40
			2	100	169	934.0			7.69	719	294	3.73	5.83				
			3	100	64	354.0			12.50	783	125	3.57	8.94				
			4	100	22	122.0			21.32	805	61	3.52	12.80				
			5	100	27	150.0		294	19.23	832	39	3.47	16.01				
			6	100	0	0.0			0.00	832	12	3.47	28.87				
			7	100	0	0.0			0.00	832	12	3.47	28.87				
			8	100	12	66.5			28.87	844	12	3.44	28.87				

6-25	7	42960908	1	100	188	1,038.0	188		7.30	188	616	7.29	4.03	17.25	29.25	37.25	1.60
			2	100	231	1,280.0			6.58	419	428	4.89	4.83				
			3	100	116	646.0			9.26	535	197	4.32	7.12				
			4	100	47	260.0			14.60	582	81	4.15	11.11				
			5	100	16	89.0		428	25.00	598	34	4.09	17.15				
			6	100	7	39.0			37.74	605	18	4.07	23.57				
			7	100	2	11.0			70.93	607	11	4.06	30.15				
			8	100	9	50.0			33.33	616	9	4.03	33.33				
6-26	8	43390932	1	100	550	3,051.0	550		4.26	550	791	4.26	3.56	7.75	14.00	21.50	0.10
			2	100	175	969.0			7.56	725	241	3.71	6.44				
			3	100	23	128.0			20.83	748	66	3.66	12.31				
			4	100	18	100.0			23.60	766	43	3.61	15.25				
			5	100	10	55.0		241	31.66	776	25	3.60	20.00				
			6	100	3	17.0			57.80	779	15	3.58	25.82				
			7	100	2	11.0			70.92	781	12	3.58	28.87				
			8	100	10	55.0			31.66	791	10	3.55	31.62				
6-26	9	43100884	1	100	575	3,190.0	575		4.17	575	799	4.17	3.54	9.50	17.75	23.25	1.60
			2	100	131	727.0			8.73	706	224	3.76	6.68				
			3	100	37	199.0			16.67	743	93	3.67	10.37				
			4	100	24	133.0			20.40	767	56	3.61	13.36				
			5	100	10	55.0		224	31.64	777	32	3.59	17.68				
			6	100	8	44.0			35.34	785	22	3.57	21.32				
			7	100	4	22.0			50.00	789	14	3.56	26.73				
			8	100	10	55.0			31.64	799	10	3.54	31.62				
6-27	10	43290949	1	100	750	4,160.0	750		3.65	750	1,137	3.65	2.97	8.75	10.10	19.25	1.60
			2	100	289	1,603.0			5.88	1,039	387	3.10	5.08				
			3	100	50	277.0			14.13	1,089	98	3.03	10.10				
			4	100	22	122.0			21.32	1,111	48	3.00	14.43				
			5	100	12	67.0		387	28.90	1,123	26	2.89	19.61				
			6	100	3	17.0			57.80	1,126	14	2.98	26.73				
			7	100	1	5.0			100.00	1,127	11	2.98	30.15				
			8	100	10	55.0			31.65	1,137	10	2.97	31.62				
6-27	11	43260944	1	100	88	485.0	88		10.70	88	289	0.66	5.88	20.00	33.50	37.50	—
			2	100	54	300.0			13.60	142	201	8.39	7.05				
			3	100	67	372.0			12.21	209	147	6.91	8.25				
			4	100	54	300.0			13.60	263	80	6.17	11.18				

* Stem Diameter, Class	Stem Diameter, Inches
1	< 1.0
2	1.0- 2.0
3	2.5- 3.6
4	4.0- 5.5
5	6.0- 7.0
6	7.5- 8.5
7	9.0- 9.5
8	10.0-30.0

Table D-4 (cont)

Date 1979	Site No	Grid Coordinates	Stem Dia Class No a/	Cell Dia	No of Stems	Stem b/ Density	Total Stems <1 in	Total Stems >1 in	Stem Class Spacing	Cum Stem Number for Diams ≤	Cum Stem Number for Diams ≥	Stem Spacing, Ft, for Dia Classes ≤	Stem Spacing, ft, for Dia Classes ≥	Average Recognition Distance for Target Heights 0	1	5	Light Intensity
				(ft)					(ft)						(ft)		(CD/ft^2)
			5	100	10	55.0		201	31.60	273	26	6.05	19.61				
			6	100	1	5.0			00.00	274	16	6.04	25.00				
			7	100	3	17.0			57.80	277	15	6.01	25.82				
			8	100	12	66.0			28.90	289	12	5.88	28.87				
6-28	12	42730945	1	100	525	2,912.0	525		4.37	525	986	436	3.18	15.50	18.50	26.75	1.60
			2	100	322	1,787.0			5.57	847	461	3.44	4.66				
			3	100	84	466.0			10.92	931	139	3.28	8.48				
			4	100	31	172.0			17.95	962	55	3.22	13.48				
			5	100	7	39.0		461	37.73	969	24	3.21	20.41				
			6	100	4	22.0			50.00	973	17	3.21	24.25				
			7	100	0	0.0			0.00	973	13	3.21	27.74				
			8	100	13	72.0			27.74	986	13	3.18	27.74				
6-28	13	42650956	1	100	162	900.0	162		7.86	162	398	7.86	5.01	9.75	16.25	24.00	1.60
			2	100	88	488.0			10.67	250	236	6.32	6.51				
			3	100	92	510.0			10.42	342	148	6.42	8.22				
			4	100	33	182.0			17.47	375	56	5.16	13.36				
			5	100	6	3.3		236.0	40.82	381	23	5.12	20.85				
			6	100	2	11.0			70.92	383	17	5.1	24.25				
			7	100	1	5.0			100.00	384	15	5.1	25.82				
			8	100	14	78.0			26.74	398	14	5.01	26.73				
7-2	14	43010932	1	100	2,500	13,866.0	2,500		2.00	2,500	2,562	2.00	1.98	11.00	13.25	14.5	1.6.0
			2	100	32	177.0			17.67	2,532	62	1.98	12.70				
			3	100	14	78.0			26.74	2,546	30	1.98	18.26				
			4	100	6	33.0			40.81	2,552	16	1.98	25.00				
			5	100	2	11.0		62	70.92	2.554	10	1.98	31.62				
			6	100	2	11.0			70.92	2,556	8	1.98	35.36				
			7	100	2	11.0			70.92	2,558	6	1.98	40.82				
			8	100	4	22.0			50.00	2,562	4	1.97	50.00				
7-2	15	42850966	1	100	451	2,504.0	451		4.71	451	1,093	4.71	3.02	18.25	46.25	50.00	0.80
			2	100	333	1,848.0			5.57	784	642	3.57	3.95				
			3	100	266	1,479.0			6.12	1,050	309	3.09	5.69				
			4	100	23	128.0			20.83	1,073	43	3.05	15.25				
			5	100	8	44.0		642	35.33	1.081	20	3.04	22.36				
			6	100	1	5.5			100.00	1,082	12	3.04	28.87				
			7	100	1	5.5			100.00	1,083	11	3.04	30.15				
			8	100	10	55.0			31.65	1,093	10	3.02	31.62				
7-3	16	42800917	1	100	36	199.0	36		16.66	36	150	16.67	8.16	29.00	30.25	42.50	13.10
			2	100	61	338.0			12.82	97	114	10.15	9.37				
			3	100	12	67.0			28.90	109	53	9.50	13.74				
			4	100	18	100.0			23.58	127	41	8.87	15.62				
			5	100	5	28.0		150	44.64	132	23	8.70	20.85				

			6	100	3	17.0			57.32	135	18	8.60	23.57				
			7	100	2	11.0			70.92	137	15	8.54	25.82				
			8	100	13	72.0			27.73	150	13	8.16	27.74				
7-3	17	43450920	1	100	10	55.0	10		31.62	10	48	31.16	14.43	19.25	22.50	40.00	26.10
			2	100	16	89.0			25.00	26	38	19.61	16.22				
			3	100	8	44.0			35.00	34	22	17.15	21.32				
			4	100	6	33.0			40.00	40	14	15.81	26.73				
			5	100	2	11.0		38	70.92	42	8	15.43	35.36				
			6	100	2	11.0			0.00	48	6	15.07	40.82				
			7	100	0	0.0			0.00	44	4	14.43	50.00				
			8		4	22.0			50.00	48	4	14.43	50.00				
7-5	18	42560972	1	100	524	3,190.0	575		4.17	525	787	4.17	3.56	9.50	17.50	26.00	1.60
			2	100	150	830.0			8.20	625	262	3.71	6.18				
			3	100	29	161.0			18.60	654	112	3.64	9.45				
			4	100	51	283.0			14.00	705	83	3.52	10.98				
			5	100	18	100.0		262	23.60	723	32	3.49	17.68				
			6	100	3	17.0			57.70	726	14	3.48	26.73				
			7	100	3	17.0			57.70	729	11	3.47	30.15				
			8	100	8	44.0			35.40	787	8	3.46	35.36				
7-5	19	43050975	1	100	725	4,022.0	725		3.71	725	831	3.71	3.47	13.00	13.00	24.74	1.60
			2	100	50	277.0			14.10	775	106	3.59	9.71				
			3	100	24	133.0			20.40	799	56	3.54	13.36				
			4	100	16	89.0			25.00	815	32	3.50	17.68				
			5	100	2	11.0		106	70.70	817	16	3.50	25.00				
			6	100	4	22.0			50.00	821	14	3.49	26.73				
			7	100	5	28.0			44.70	826	10	3.48	31.62				
			8	100	5	28.0			44.70	831	5	3.47	44.72				
7-10	20	70970916	1	100	3,700	20,521.0	3,700		1.64	3,700	4,088	1.64	1.56	3.00	3.00	3.00	3.20
			2	100	322	1,788.0			5.57	4,022	388	1.58	5.08				
			3	100	27	150.0			19.25	4,049	66	1.57	12.31				
			4	100	12	66.0			28.87	4,061	39	1.57	16.01				
			5	100	17	39.0		388	37.79	4,078	27	1.57	19.25				
			6	100	6	33.0			40.83	4,084	10	1.56	31.62				
			7	100	2	11.0			70.72	4,086	4	1.56	50.00				
			8	100	2	11.0			70.72	4,088	2	1.56	70.71				

* Stem Diameter, Class	Stem Diameter, Inches
1	< 1.0
2	1.0- 2.0
3	2.5- 3.6
4	4.0- 5.5
5	6.0- 7.0
6	7.5- 8.5
7	9.0- 9.5
8	10.0-30.0

Table D-4 (concluded)

Date 1979	Site No	Grid Coordinates	Stem Dia Class No a/	Cell Dia (ft)	No of Stems	Stem b/ Density	Total Stems <1 in	Total Stems >1 in	Stem Class Spacing (ft)	Cum Stem Number for Diams ≤	Cum Stem Number for Diams ≥	Stem Spacing, Ft, for Dia Classes ≤	Stem Spacing, ft, for Dia Classes ≥	Average Recognition Distance for Target Heights (ft) 0	1	5	Light Intensity (CD/ft^2)
7-11	21	39330918	1	100	1,350	5,926.0	1,350		3.06	1,350	2,080	2.72	2.19	5.50	6.25	7.75	1.60
			2	100	650	3,606.0			3.92	2,000	730	2.24	3.70				
			3	100	41	1,952.0			15.68	2,041	80	2.21	11.18				
			4	100	14	78.0			26.73	2,055	39	2.21	16.01				
			5	100	6	33.0		730	40.82	2,061	25	2.20	20.00				
			6	100	4	22.0			20.00	2,065	19	2.20	22.94				
			7	100	3	17.0			57.80	2,068	15	2.20	25.82				
			8	100	12	66.0			28.90	2,080	12	2.19	28.87				
7-12	22	39400913	1	100	625	3,467.0	625		4.00	625	894	4.00	3.34	9.25	12.75	23.75	--
			2	100	212	476.0			6.86	837	269	3.46	6.10				
			3	100	15	83.2			25.82	852	57	3.43	13.25				
			4	100	14	77.6			26.70	866	42	3.40	15.43				
			5	100	5	28.0		269	44.72	871	28	3.39	18.90				
			6	100	4	22.0			50.00	875	23	3.38	20.85				
			7	100	2	11.0			70.70	877	19	3.38	22.94				
			8	100	17	94.0			24.50	894	17	3.34	24.25				
7-12	23	39650870	1	100	650	3,606.0	650		3.90	650	861	3.92	3.41	9.50	14.50	20.25	1.60
			2	100	125	692.0			8.90	775	211	3.59	6.88				
			3	100	47	260.0			14.60	822	86	3.49	10.78				
			4	100	15	83.2			25.80	837	39	3.46	16.01				
			5	100	8	44.0		211	35.30	845	24	3.44	20.41				
			6	100	1	5.0			100.00	846	16	3.44	25.00				
			7	100	2	11.0			70.70	848	15	3.43	25.82				
			8	100	13	72.1			27.70	861	13	13.41	27.74				
7-12	24	37700857	Grass	100										3.00	3.00	3.00	104.00
7-13	25	35450810	1	100	194	1,076.0	194		7.18	194	296	7.18	5.81	13.75	18.00	31.50	1.60
			2	100	58	321.0			13.15	252	102	6.30	9.90				
			3	100	14	78.0			26.73	266	44	6.13	15.08				
			4	100	8	44.0			35.36	274	30	6.04	18.26				
			5	100	8	44.0		102	35.36	282	22	5.95	21.32				
			6	100	3	17.0			57.73	285	14	5.92	26.73				
			7	100	5	28.0			44.72	290	11	5.87	30.15				
			8	100	6	33.0			40.82	296	6	5.81	40.82				
7-13	26	36350870	1	100	500	2,774.0	500		4.47	500	753	4.47	3.64	18.50	35.00	50.75	0.80
			2	100	188	1,042.0			7.30	688	253	3.81	6.29				
			3	100	27	150.0			19.25	715	65	3.74	12.40				
			4	100	16	89.0			25.00	731	38	3.70	16.22				
			5	100	10	55.0		253	31.62	741	22	3.67	21.32				
			6	100	3	17.0			57.70	744	12	3.67	28.87				
			7	100	1	5.5			100.00	745	9	3.66	33.33				
			8	100	8	44.0			35.36	753	8	3.64	35.36				

7-16	27	41250897	1	100	23	128.0	23		20.85	23	122	20.85	9.05	17.00	28.25	40.25	34.60
			2	100	27	150.0			19.25	50	99	14.14	10.05				
			3	100	30	166.0			18.26	80	72	11.18	11.79				
			4	100	15	83.0			25.82	95	42	10.26	15.43				
			5	100	9	50.0		99	33.30	104	27	9.81	19.25				
			6	100	3	17.0			57.73	107	18	9.67	23.57				
			7	100	4	22.0			50.00	111	15	9.49	25.82				
			8	100	11	61.0			30.15	122	11	9.05	30.15				
7-17	28	40320852	1	100	278	1,540.0	278		6.00	278	399	6.00	5.01	5.25	19.25	43.76	13.10
			2	100	35	194.0			16.90	313	121	5.65	9.09				
			3	100	34	189.0			17.10	347	86	5.37	10.78				
			4	100	28	155.0			18.90	375	52	5.16	13.87				
			5	100	12	67.0		121	28.90	387	24	5.08	20.41				
			6	100	3	17.0			57.70	390	12	5.06	28.87				
			7	100	3	17.0			57.70	393	9	5.04	33.33				
			8	100	6	33.0			40.80	399	6	5.01	40.82				
7-17	28	42260908	1	100	600	3,329.0	600		4.08	600	821	4.08	3.49	16.00	20.50	31.00	1.60
			2	100	156	868.0			8.00	756	221	3.64	6.73				
			3	100	24	133.0			20.41	780	65	3.58	12.40				
			4	100	18	0.0			23.57	798	41	3.54	15.62				
			5	100	12	67.0		221	28.87	810	23	3.51	20.85				
			6	100	7	39.0			37.80	817	11	3.50	30.15				
			7	100	1	5.5			100.00	818	4	3.50	50.00				
			8	100	3	17.0			57.74	821	3	3.49	57.74				
7-18	30	40480985	1	100	322	1,787.0	322		5.60	322	425	5.57	4.85	16.76	30.25	47.50	1.60
			2	100	55	308.0			13.40	377	103	5.15	9.85				
			3	100	15	83.0			25.60	392	48	5.05	14.43				
			4	100	12	67.0			28.90	404	33	4.98	17.41				
			5	100	8	44.0		103	35.00	412	21	4.93	21.82				
			6	100	2	11.0			70.70	414	13	4.91	27.74				
			7	100	2	11.0			70.70	416	11	4.90	30.15				
			8	100	9	50.0			33.00	425	9	4.85	33.33				
7-18	31	40580937	1	100	2,200	12,201.0	2,200		2.13	2,200	2,388	2.13	2.05	6.25	11.00	25.75	13.10
			2	100	112	620.0			9.40	2,312	188	2.08	7.29				
			3	100	34	189.0			17.10	2,346	76	2.06	11.47				
			4	100	15	83.0			25.80	2,361	42	2.06	15.43				
			5	100	10	55.0		188	31.60	2,371	27	2.05	19.25				
			6	100	4	22.0			50.00	2,375	17	2.05	24.25				
			7	100	4	50.0			50.00	2,379	13	2.05	27.74				
			8	100	9	50.0			33.00	2,388	9	2.05	33.33				

* Stem Diameter, Class	Stem Diameter, Inches
1	< 1.0
2	1.0- 2.0
3	2.5- 3.6
4	4.0- 5.5
5	6.0- 7.0
6	7.5- 8.5
7	9.0- 9.5
8	10.0-30.0

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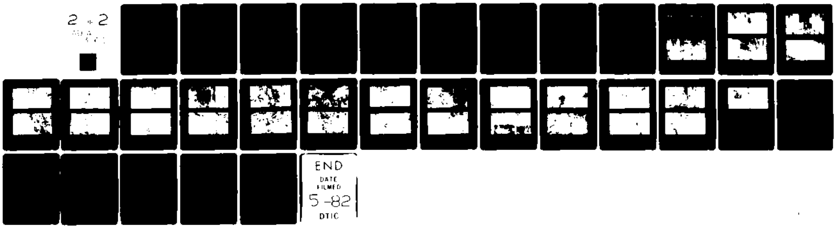

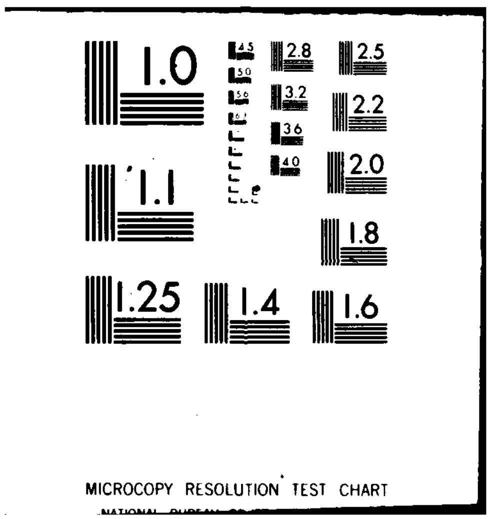
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MICROCOPY RESOLUTION TEST CHART

TABLE D-4. SUMMARY OF VEGETATION DATA--STRUCTURAL CELL METHOD

Date	Site No.	Grid Coordinates	Stem Spacing, Quadrant (ft) 1	2	3	4	Stem Diameter, Quadrant (in) 1	2	3	4	Stem Height, Quadrant (ft) 1	2	3	4	Average Stem Spacing, (ft)	Average Stem Diameter, (in)	Average Stem Height, (in)	Density (stems/acre)
6-20	1	43250905	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6-20	2	43080911	12.0	15.0	9.0	10.0	4.5	9.0	19.0	2.0	51.0	65.0	85.0	75.0	—	—	—	—
			5.0	8.0	11.0	11.0	5.0	2.5	9.0	2.5	17.0	24.0	48.0	21.0	—	—	—	—
			3.0	4.0	2.0	8.5	1.0	1.5	1.0	2.0	15.0	24.0	18.0	21.0	—	—	—	—
			10.0	9.0	12.0	6.0	8.0	1.5	3.5	6.0	48.0	20.0	32.0	37.0	—	—	—	—
			5.0	3.0	6.0	6.0	7.0	1.5	2.0	1.5	40.0	15.0	7.0	20.0	7.82	3.62	29.00	712.00
			15.0	5.0	9.5	9.0	1.5	2.0	1.0	3.0	15.0	18.0	14.0	28.0	—	—	—	—
			7.0	6.5	5.0	4.0	2.5	4.0	5.0	2.0	22.0	35.0	52.0	15.0	—	—	—	—
			12.0	10.0	5.0	2.5	1.5	5.5	3.5	2.0	18.0	48.0	12.0	14.0	—	—	—	—
			12.0	11.0	3.0	4.0	3.0	2.5	1.5	3.0	18.0	23.0	18.0	26.0	—	—	—	—
			5.0	5.0	8.5	8.0	2.5	1.5	5.5	2.0	22.0	24.0	40.0	19.0	—	—	—	—
6-21	3	43150948	5.4	1.0	11.0	11.0	3.0	3.0	2.0	4.0	30.0	18.0	8.0	30.0	—	—	—	—
			20.0	8.0	3.0	6.0	5.5	10.5	1.0	2.5	30.0	55.0	8.0	24.0	—	—	—	—
			9.0	3.0	16.0	5.0	4.0	6.0	3.5	3.5	32.0	40.0	30.0	28.0	—	—	—	—
			9.0	14.0	4.0	7.0	4.0	3.5	4.5	2.0	29.0	30.0	25.0	14.0	—	—	—	—
			6.0	8.0	4.0	12.0	1.0	1.5	4.5	1.0	16.0	12.0	46.0	14,0	7.35	3.57	27.05	806.00
			5.0	3.0	6.0	8.0	2.0	2.0	4.0	5.0	22.0	21.0	38.0	46.0	—	—	—	—
			1.0	3.0	4.0	11.0	1.0	1.5	1.0	6.0	9.0	24.0	12.0	27.0	—	—	—	—
			8.0	8.0	3.0	4.0	2.0	2.0	1.0	5.0	22.0	22.0	14.0	48.0	—	—	—	—
			14.0	6.0	3.0	12.0	4.0	7.5	2.0	10.0	46.0	50.0	22.0	27.0	—	—	—	—
			10.0	15.0	4.0	4.0	8.0	1.5	2.0	5.0	26.0	22.0	26.0	39.0	—	—	—	—
6-21	4	42900941	8.0	22.0	14.0	20.0	8.0	28.0	6.0	3.0	44.0	48.0	22.0	21.0	—	—	—	—
			9.0	15.0	4.0	5.0	4.0	5.0	5.0	4.0	20.0	58.0	20.0	24.0	—	—	—	—
			45.0	22.0	17.0	20.0	4.0	7.0	6.0	4.0	30.0	43.0	36.0	26.0	—	—	—	—
			4.0	30.0	13.0	3.0	12.0	3.0	9.0	5.0	65.0	20.0	41.0	27.0	—	—	—	—
			2.0	3.0	14.0	15.0	3.0	12.0	2.0	14.0	20.0	45.0	24.0	32.0	15.75	7.70	35.90	176.00
			15.0	3.0	22.0	15.0	1.0	2.0	12.0	7.0	99.0	12.0	45.0	26.0	—	—	—	—
			60.0	35.0	25.0	40.0	12.0	6.0	10.0	12.0	66.0	28.0	48.0	48.0	—	—	—	—
			4.0	5.0	6.0	50.0	12.0	6.0	10.0	14.0	25.0	26.0	40.0	53.0	—	—	—	—
			4.0	4.0	4.0	4.0	12.0	6.0	11.0	6.0	70.0	21.0	55.0	46.0	—	—	—	—
			15.0	5.0	25.0	4.0	10.0	4.0	2.0	10.0	32.0	26.0	18.0	64.0	—	—	—	—
6-22	5	42960921	7.0	9.0	16.0	12.0	3.0	12.0	14.0	4.0	32.0	55.0	35.0	26.0	—	—	—	—
			12.0	7.0	4.0	2.0	3.0	12.0	3.0	2.0	23.0	55.0	24.0	9.0	—	—	—	—
			15.0	6.0	12.0	10.0	3.0	3.0	2.0	2.0	18.0	18.0	14.0	18.0	—	—	—	—
			4.0	10.0	12.0	4.0	1.0	4.0	7.0	2.0	18.0	32.0	29.0	21.0	—	—	—	—
			5.0	12.0	3.0	6.0	1.0	7.0	1.0	4.0	16.0	29.0	11.0	27.0	7.75	5.05	24.35	725.00

			11.0	6.0	3.0	10.0	2.0	2.0	3.0	2.0	12.0	13.0	23.0	20.0	—	—	—	—
			6.0	4.0	12.0	10.0	3.0	17.0	8.0	10.0	16.0	35.0	45.0	28.0	—	—	—	—
			4.0	10.0	16.0	4.0	1.0	1.0	2.0	22.0	20.0	13.0	26.0	30.0	—	—	—	—
			1.0	6.0	8.0	5.0	8.0	1.0	3.0	3.0	36.0	14.0	16.0	7.0	—	—	—	—
			3.0	5.0	14.0	4.0	11.0	3.0	8.0	2.0	15.0	17.0	42.0	16.0	—	—	—	—
6-22	6	43020925	7.0	10.0	14.0	10.0	38.0	2.0	1.0	3.0	65.0	23.0	16.0	17.0	—	—	—	—
			5.0	7.0	6.0	5.0	6.0	4.0	4.0	4.0	31.0	30.0	25.0	12.0	—	—	—	—
			7.0	6.0	4.0	14.0	2.0	6.0	3.0	4.0	14.0	42.0	17.0	27.0	—	—	—	—
			3.0	12.0	10.0	2.0	2.0	6.0	20.0	2.0	16.0	28.0	15.0	12.0	—	—	—	—
			3.0	11.0	13.0	14.0	2.0	7.0	9.0	8.0	12.0	55.0	58.0	17.0	—	—	—	—
			9.0	18.0	9.0	2.0	20.0	24.0	8.0	5.0	17.0	18.0	56.0	31.0	8.08	7.40	28.40	667.00
			6.0	6.0	27.0	1.0	8.0	3.0	20.0	3.0	59.0	22.0	17.0	26.0	—	—	—	—
			4.0	4.0	5.0	13.0	2.0	3.0	5.0	[illegible]	13.0	28.0	43.0	23.0	—	—	—	—
			3.0	7.0	9.0	11.0	3.0	[illegible]	5.0	4.0	30.0	30.0	40.0	27.0	—	—	—	—
			8.0	8.0	2.0	8.0	7.0	[illegible]	3.0	7.0	44.0	17.0	12.0	49.0	—	—	—	—
6-25	7	42960908	2.5	4.5	12.0	8.0	1.5	3.0	8.0	1.0	7.0	28.0	48.0	8.0	—	—	—	—
			6.5	8.0	11.0	9.0	1.0	2.0	3.5	3.0	15.0	20.0	35.0	22.0	—	—	—	—
			4.0	1.0	7.0	7.5	1.5	3.0	13.0	2.0	22.0	22.0	55.0	15.0	—	—	—	—
			7.0	12.0	11.0	5.5	3.5	1.5	6.0	9.0	25.0	15.0	50.0	52.0	—	—	—	—
			3.0	2.0	7.0	3.5	6.5	7.0	2.5	2.5	55.0	55.0	26.0	25.0	6.50	3.90	29.00	1,030.00
			4.0	11.0	12.0	9.0	5.0	2.0	3.0	3.0	35.0	26.0	26.0	15.0	—	—	—	—
			4.0	8.0	5.0	3.5	4.0	3.5	1.5	2.0	32.0	45.0	7.0	10.0	—	—	—	—
			6.0	3.0	2.5	7.0	1.5	1.5	2.0	18.0	20.0	15.0	9.0	45.0	—	—	—	—
			4.0	4.5	7.0	13.0	7.5	2.0	2.5	4.0	48.0	26.0	35.0	42.0	—	—	—	—
			4.0	6.0	9.0	7.0	4.0	2.0	2.5	4.0	20.0	28.0	30.0	40.0	—	—	—	—
6-26	8	43390932	2.0	4.0	10.0	4.0	18.0	1.5	1.0	1.0	52.0	24.0	18.0	20.0	—	—	—	—
			5.0	5.0	3.0	3.0	1.0	1.0	2.0	1.0	8.0	17.0	21.0	24.0	—	—	—	—
			3.0	5.0	4.0	4.0	1.0	7.0	2.0	1.0	18.0	48.0	14.0	13.0	—	—	—	—
			5.0	7.0	14.0	3.0	1.0	2.0	6.0	1.0	9.0	15.0	16.0	18.0	—	—	—	—
			8.0	9.0	4.0	1.0	3.0	1.0	2.0	3.0	15.0	13.0	13.0	23.0	—	—	—	—
			3.0	8.0	10.0	5.0	2.0	3.0	1.0	1.0	15.0	28.0	14.0	13.0	—	—	—	—
			4.0	2.0	6.0	3.0	1.5	1.5	3.0	2.0	13.0	14.0	20.0	11.0	5.40	2.60	18.60	1,494.00
			5.0	10.0	2.0	3.0	1.5	8.0	4.0	5.0	16.0	48.0	12.0	35.0	—	—	—	—
			4.0	5.0	3.0	5.0	2.0	2.0	1.0	3.0	15.0	13.0	12.0	12.0	—	—	—	—
			4.0	6.0	9.0	15.0	2.0	3.0	1.5	1.0	15.0	12.0	10.0	15.0	—	—	—	—
6-26	9	43100884	2.0	3.0	6.0	7.0	3.0	4.0	4.0	12.0	26.0	43.0	21.0	56.0	—	—	—	—
			4.0	4.0	4.0	8.0	3.0	12.0	3.0	1.0	18.0	56.0	12.0	9.0	—	—	—	—
			3.0	2.0	3.0	3.0	5.0	3.0	12.0	3.0	45.0	18.0	56.0	45.0	—	—	—	—
			3.0	3.0	1.0	2.0	2.5	1.0	4.0	2.0	30.0	13.0	32.0	24.0	—	—	—	—
			4.0	6.0	4.0	6.0	3.5	3.5	1.0	1.0	40.0	36.0	18.0	12.0	—	—	—	—
			1.0	4.0	2.0	3.0	5.0	1.0	1.0	2.0	30.0	11.0	10.0	14.0	3.90	4.20	28.20	2,863.00
			6.0	1.0	3.0	4.0	2.5	3.0	2.5	7.0	13.0	28.0	28.0	46.0	—	—	—	—
			2.0	6.0	11.0	9.0	1.0	1.0	4.0	2.0	12.0	12.0	22.0	26.0	—	—	—	—
			2.0	1.0	4.0	5.0	1.0	9.0	14.0	1.5	9.0	48.0	54.0	30.0	—	—	—	—
			3.0	1.0	2.0	8.0	14.0	1.0	7.0	3.5	58.0	10.0	33.0	26.0	—	—	—	—
6-28	10	43290949	3.0	2.0	6.0	2.0	1.0	2.0	1.0	2.0	12.0	15.0	12.0	13.0	—	—	—	—
			3.0	4.0	6.0	8.0	1.0	1.0	3.0	4.0	13.0	15.0	22.0	38.0	—	—	—	—
			4.0	8.0	5.0	4.0	1.5	1.5	4.5	6.0	16.0	17.0	29.0	45.0	—	—	—	—
			3.0	4.0	6.0	3.0	6.0	1.0	1.5	1.0	50.0	13.0	20.0	12.0	—	—	—	—

Table D-5 (cont)

Date	Site No.	Grid Coordinates	Stem Spacing, Quadrant 1	2	3	4	Stem Diameter, Quadrant 1	2	3	4	Stem Height, Quadrant 1	2	3	4	Average Stem Spacing, (ft)	Average Stem Diameter, (in)	Average Stem Height, (in)	Density (stems/acre)
			(ft)				(in)				(ft)							
			2.0	7.0	6.0	6.0	3.0	18.0	1.5	1.0	20.0	34.0	15.0	17.0	5.20	2.90	21.00	1,610.00
			5.0	6.0	4.0	4.0	3.0	1.0	2.5	7.0	36.0	17.0	27.0	22.0	—	—	—	—
			8.0	4.0	1.0	8.0	1.5	2.0	1.0	7.0	9.0	23.0	12.0	20.0	—	—	—	—
			3.0	5.0	4.0	6.0	1.0	1.0	4.0	1.0	13.0	18.0	13.0	17.0	—	—	—	—
			9.0	4.0	6.0	4.0	6.0	3.0	1.0	5.5	42.0	17.0	13.0	37.0	—	—	—	—
			10.0	12.0	8.0	4.0	2.0	2.0	1.0	2.5	14.0	22.0	12.0	31.0	—	—	—	—
6-29	11	43260944	5.0	12.0	5.0	4.0	4.5	8.0	3.0	2.0	17.0	24.0	25.0	11.0	—	—	—	—
			3.0	5.0	9.0	6.0	29.0	3.0	2.0	4.5	75.0	14.0	10.0	30.0	—	—	—	—
			16.0	4.0	4.0	12.0	2.5	2.5	17.0	4.0	27.0	7.0	88.0	40.0	—	—	—	—
			7.0	4.0	7.0	2.0	2.5	4.5	4.0	4.0	25.0	26.0	27.0	28.0	—	—	—	—
			3.0	10.0	8.0	9.0	4.0	4.5	6.0	6.5	31.0	32.0	39.0	39.0	6.80	5.28	28.70	942.00
			6.0	4.0	9.0	9.0	8.0	9.0	5.5	6.0	47.0	53.0	26.0	30.0	—	—	—	—
			4.0	5.0	2.0	5.0	4.5	6.5	4.0	1.5	25.0	23.0	22.0	20.0	—	—	—	—
			1.0	1.0	6.0	8.0	1.5	1.5	3.0	6.0	22.0	13.0	24.0	37.0	—	—	—	—
			20.0	4.0	13.0	11.0	6.5	5.0	4.0	3.5	29.0	27.0	22.0	18.0	—	—	—	—
			1.0	14.0	6.0	6.0	3.5	5.0	4.5	4.0	17.0	29.0	9.0	38.0	—	—	—	—
6-28	12	42730945	26.0	4.0	14.0	4.0	5.0	3.5	2.0	1.0	29.0	22.0	13.0	13.0	—	—	—	—
			4.0	15.0	4.0	7.0	14.0	4.0	2.0	1.0	54.0	30.0	16.0	9.0	—	—	—	—
			4.0	35.0	9.0	6.0	3.0	3.0	4.5	2.5	9.0	15.0	23.0	19.0	—	—	—	—
			6.0	[illegible]	4.0	8.0	19.0	1.5	3.0	1.0	44.0	11.0	24.0	13.0	—	—	—	—
			21.0	[illegible]	4.0	14.0	5.0	18.0	3.0	15.0	33.0	28.0	5.0	55.0	8.50	4.40	23.50	603.00
			3.0	[illegible]	4.0	5.0	4.5	6.0	1.0	6.0	33.0	40.0	7.0	47.0	—	—	—	—
			6.0	[illegible]	14.0	18.0	12.0	5.0	2.0	5.0	48.0	31.0	16.0	42.0	—	—	—	—
			3.0	[illegible]	3.0	3.0	1.0	1.0	1.5	1.0	8.0	11.0	18.0	12.0	—	—	—	—
			9.0	[illegible]	13.0	6.0	2.0	1.0	6.0	2.0	11.0	14.0	38.0	14.0	—	—	—	—
			4.0	[illegible]	4.0	2.0	3.0	1.0	1.0	4.0	27.0	13.0	9.0	37.0	—	—	—	—
6-28	13	42650956	5.0	1.0	8.0	11.0	4.0	2.0	1.0	3.0	26.0	19.0	9.0	8.0	—	—	—	—
			12.0	2.0	6.0	4.0	3.0	2.0	1.0	3.0	24.0	15.0	9.0	31.0	—	—	—	—
			11.0	1.0	13.0	3.0	4.0	2.0	3.0	1.0	33.0	22.0	18.0	11.0	—	—	—	—
			7.0	14.0	6.0	9.0	2.0	4.0	4.0	3.0	13.0	40.0	19.0	28.0	—	—	—	—
			3.0	3.0	4.0	11.0	5.0	2.0	2.0	4.0	24.0	19.0	16.0	27.0	—	—	—	—
			1.0	6.0	6.0	10.0	5.0	3.0	1.0	2.0	24.0	9.0	4.0	13.0	6.80	3.90	19.80	942.00
			2.0	6.0	4.0	7.0	1.0	5.0	1.0	3.0	9.0	38.0	8.0	12.0	—	—	—	—
			2.0	2.0	32.0	4.0	1.0	4.0	12.0	1.0	13.0	26.0	55.0	7.0	—	—	—	—
			6.0	4.0	4.0	4.0	1.0	1.0	2.5	1.0	8.0	11.0	26.0	14.0	—	—	—	—
			4.0	12.0	6.0	18.0	1.0	1.0	1.0	14.0	53.0	8.0	11.0	32.0	—	—	—	—
7-02	14	43010932	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7-02	15	42850966	18.0	2.0	12.0	6.0	26.0	3.0	3.0	1.0	65.0	28.0	24.0	15.0	—	—	—	—
			4.0	2.0	3.0	2.0	1.0	1.0	3.5	5.0	13.0	14.0	27.0	30.0	—	—	—	—
			4.0	5.0	4.0	6.0	1.0	1.0	15.0	3.0	12.0	7.0	40.0	25.0	—	—	—	—
			4.0	3.0	1.0	6.0	1.0	2.5	9.0	1.0	12.0	27.0	43.0	11.0	—	—	—	—
			1.0	3.0	7.0	4.0	3.0	1.0	1.0	1.0	30.0	12.0	20.0	31.0	—	—	—	—
			3.0	4.0	3.0	1.0	1.0	1.0	1.0	4.0	9.0	11.0	14.0	26.0	4.90	3.70	22.50	1,814.00
			12.0	1.0	6.0	9.0	3.0	2.0	3.0	17.0	35.0	19.0	22.0	41.0	—	—	—	—
			4.0	6.0	9.0	1.0	4.5	2.0	3.5	3.0	27.0	17.0	28.0	22.0	—	—	—	—
			9.0	2.0	2.0	4.0	2.0	3.0	2.0	1.0	15.0	21.0	18.0	9.0	—	—	—	—
			8.0	6.0	4.0	4.0	4.5	1.5	3.0	3.5	26.0	12.0	18.0	27.0	—	—	—	—
7-03	16	42800917	6.0	3.0	1.0	30.0	8.0	2.0	4.0	20.0	35.0	19.0	29.0	55.0	—	—	—	—
			5.0	3.0	11.0	10.0	1.0	1.0	16.0	1.0	18.0	13.0	47.0	10.0	—	—	—	—
			2.0	4.0	4.0	2.0	2.0	2.0	1.0	1.0	28.0	6.0	31.0	7.0	—	—	—	-
			3.0	3.0	4.0	5.0	4.5	15.0	3.0	1.0	16.0	7.0	26.0	19.0	—	—	—	—
			6.0	20.0	2.0	1.0	2.0	3.0	1.0	2.0	15.0	39.0	21.0	22.0	—	—	—	—
			6.0	3.0	2.0	4.0	2.5	4.0	1.0	18.0	23.0	33.0	6.0	47.0	6.50	4.80	23.80	1,030.00
			6.0	8.0	12.0	13.0	13.0	3.0	2.0	3.0	2.0	22.0	27.0	32.0	—	—	—	—
			22.0	4.0	8.0	4.0	33.0	3.0	2.0	1.5	26.0	27.0	20.0	19.0	—	—	—	—
			6.0	8.0	5.0	21.0	1.0	3.0	1.0	2.0	5.0	36.0	1.0	9.0	—	—	—	—
			4.0	6.0	5.0	6.0	2.5	9.0	4.0	4.5	26.0	37.0	27.0	36.0	—	—	—	—
7-03	17	43450920	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7-05	18	42560972	12.0	9.0	13.0	2.0	3.0	4.0	4.0	1.5	23.0	19.0	34.0	19.0	—	—	—	—
			5.0	18.0	6.0	8.0	8.0	3.0	4.0	2.0	48.0	29.0	31.0	28.0	—	—	—	—
			5.0	3.0	3.0	5.0	7.0	1.0	4.0	6.0	31.0	14.0	34.0	27.0	—	—	—	—
			6.0	9.0	22.0	3.0	2.0	2.0	2.0	3.0	31.0	19.0	28.0	24.0	—	—	—	—
			2.0	6.0	13.0	5.0	1.0	1.0	3.0	8.0	9.0	12.0	27.0	40.0	—	—	—	—
			5.0	8.0	14.0	3.0	5.0	3.0	2.0	3.0	36.0	13.0	29.0	12.0	7.70	3.75	24.30	725.00
			9.0	6.0	4.0	4.0	4.0	5.0	8.0	3.0	14.0	24.0	8.0	19.0	—	—	—	—
			6.0	12.0	18.0	4.0	3.0	3.4	3.0	5.0	26.0	9.0	37.0	22.0	—	—	—	—
			5.0	8.0	7.0	6.0	3.5	4.0	5.0	8.0	22.0	19.0	33.0	31.0	—	—	—	—
			22.0	1.0	5.0	9.0	5.0	1.0	4.0	3.0	17.0	9.0	6.0	24.0	—	—	—	—
7-05	19	43050975	12.0	8.0	22.0	18.0	5.0	6.5	4.0	3.0	28.0	48.0	12.0	21.0	—	—	—	—
			13.0	11.0	3.0	8.0	15.0	6.0	<1.0	<1.0	32.0	30.0	6.0	11.0	—	—	—	—
			4.0	6.0	10.0	15.0	1.0	26.0	7.5	4.0	6.0	28.0	54.0	30.0	—	—	—	—
			3.0	3.0	8.0	2.0	2.0	6.0	3.0	1.0	19.0	55.0	26.0	12.0	—	—	—	—
			11.0	20.0	15.0	8.0	>2.0	1.0	9.0	5.0	90.0	6.0	85.0	37.0	—	—	—	—
			12.0	6.0	9.0	15.0	5.0	1.0	3.5	4.0	31.0	12.0	7.0	34.0	11.55	6.20	28.50	328.00
			12.0	18.0	3.0	18.0	1.0	12.0	3.0	1.0	11.0	55.0	12.0	11.0	—	—	—	—

Table D-5 (cont)

Date	Site No.	Grid Coordinates	Stem Spacing, Quadrant 1 (ft)	2	3	4	Stem Diameter, Quadrant 1 (in)	2	3	4	Stem Height, Quadrant 1 (ft)	2	3	4	Average Stem Spacing, (ft)	Average Stem Diameter, (in)	Average Stem Height, (in)	Density (stems/acre)
			15.0	10.0	15.0	15.0	5.0	4.0	2.0	1.0	27.0	18.0	7.0	7.0	—	—	—	—
			22.0	14.0	4.0	4.0	3.0	1.0	1.0	1.0	29.0	12.0	16.0	11.0	—	—	—	—
			15.0	10.0	15.0	20.0	8.0	4.0	2.0	6.0	75.0	30.0	20.0	80.0	—	—	—	—
7-10	20	40970916	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7-10	21	39330918	1.0	3.0	8.0	19.0	1.0	2.5	3.0	5.5	13.0	18.0	15.0	37.0	—	—	—	—
			10.0	2.5	5.0	4.5	1.5	1.0	2.0	2.0	16.0	14.0	12.0	23.0	—	—	—	—
			11.0	4.0	12.0	8.0	1.0	1.0	1.5	2.5	18.0	30.0	20.0	26.0	—	—	—	—
			13.0	4.0	6.0	13.0	3.0	1.5	1.0	2.0	18.0	14.0	15.0	27.0	—	—	—	—
			5.0	2.0	20.0	2.0	6.0	3.0	4.0	1.0	37.0	20.0	15.0	11.0	—	—	—	—
			3.0	1.5	2.0	3.0	1.0	1.0	1.5	4.0	12.0	8.0	14.0	37.0	6.30	29.60	23.22	1,097.00
			4.0	12.0	6.0	8.0	1.0	15.0	2.0	1.0	11.0	56.0	31.0	11.0	—	—	—	—
			4.0	4.0	6.0	1.5	1.0	10.0	1.0	1.0	9.0	65.0	13.0	15.0	—	—	—	—
			2.0	3.0	4.0	3.0	1.5	3.0	10.0	3.5	12.0	21.0	68.0	21.0	—	—	—	—
			5.0	14.0	16.0	8.0	2.5	3.0	7.0	1.5	22.0	23.0	64.0	17.0	—	—	—	—
7-12	22	39400913	3.0	5.0	4.0	11.0	1.5	1.0	2.0	1.0	16.0	11.0	12.0	14.0	—	—	—	—
			7.0	4.0	6.0	8.0	2.0	1.5	1.0	2.0	15.0	18.0	14.0	23.0	—	—	—	—
			2.0	3.0	8.0	6.0	3.0	1.0	3.0	18.0	12.0	17.0	21.0	46.0	—	—	—	—
			12.0	2.0	13.0	15.0	16.0	2.0	2.0	2.0	46.0	29.0	14.0	4.0	—	—	—	—
			2.0	4.0	3.0	8.0	3.5	1.0	2.5	1.0	18.0	9.0	21.0	12.0	5.825	3.30	17.72	1,284.00
			4.0	9.0	5.0	4.0	1.0	1.0	1.0	1.0	17.0	15.0	14.0	4.0	—	—	—	—
			3.0	12.0	12.0	7.0	1.0	1.5	18.0	1.0	18.0	11.0	42.0	11.0	—	—	—	—
			5.0	4.0	4.0	1.0	3.0	1.0	18.0	1.0	23.0	9.0	38.0	15.0	—	—	—	—
			2.0	3.0	4.0	5.0	1.0	1.0	1.5	5.0	11.0	9.0	8.0	32.0	—	—	—	—
			7.0	1.0	8.0	7.0	5.0	1.0	1.0	1.0	36.0	19.0	21.0	14.0	—	—	—	—
7-12	23	39650870	8.0	22.0	8.0	6.0	14.0	16.0	4.0	1.5	57.0	27.0	19.0	21.0	—	—	—	—
			4.0	5.0	2.0	12.0	2.0	1.0	1.0	15.0	12.0	13.0	18.0	35.0	—	—	—	—
			6.0	11.0	11.0	3.0	8.0	1.5	1.5	1.0	52.0	19.0	14.0	15.0	—	—	—	—
			1.0	2.0	4.0	6.0	4.0	1.0	1.0	1.0	14.0	14.0	15.0	13.0	—	—	—	—
			12.0	3.0	2.0	5.0	1.0	<1.0	1.0	1.5	13.0	11.0	14.0	16.0	6.45	2.80	19.03	1,047.00
			2.0	4.0	3.0	22.0	4.0	1.0	1.0	2.0	24.0	16.0	11.0	25.0	—	—	—	—
			2.0	4.0	8.0	3.0	3.0	1.0	2.0	1.0	18.0	16.0	19.0	26.0	—	—	—	—
			6.0	22.0	9.0	12.0	1.0	2.0	1.0	1.0	27.0	23.0	19.0	17.0	—	—	—	—
			3.0	2.0	3.0	5.0	1.5	<1.0	1.0	1.5	14.0	8.0	14.0	16.0	—	—	—	—
			2.0	4.0	6.0	3.0	2.0	3.0	1.0	3.0	12.0	24.0	13.0	7.0	—	—	—	—
	24	37700857	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7-13	25	35450810	26.0	5.0	1.0	4.0	5.0	1.0	3.0	1.0	36.0	12.0	28.0	16.0	—	—	—	—
			6.0	6.5	5.0	20.0	1.5	<1.0	1.0	14.0	9.0	9.0	17.0	53.0	—	—	—	—
			9.0	10.0	1.0	7.0	<1.0	1.0	4.0	3.0	6.0	11.0	9.0	24.0	—	—	—	—
			6.0	8.5	1.5	9.0	2.5	2.5	<1.0	4.0	15.0	27.0	9.0	21.0	—	—	—	—
			7.0	6.0	1.0	5.0	1.0	2.0	1.0	1.0	14.0	11.0	9.0	12.0	7.125	2.74	20.30	—
			7.0	4.0	18.0	8.0	<1.0	8.0	3.5	13.0	10.0	52.0	22.0	68.0	—	—	—	—
			12.0	6.0	18.0	1.0	1.0	2.0	2.0	1.0	14.0	17.0	21.0	8.0	—	—	—	—
			3.0	3.0	5.0	8.5	<1.0	<1.0	4.0	1.5	15.0	22.0	49.0	12.0	—	—	—	—
			4.0	9.0	12.0	3.0	1.0	3.0	6.0	1.0	11.0	22.0	42.0	14.0	—	—	—	—
			5.0	4.0	4.0	6.0	<1.0	1.0	4.5	1.5	6.0	15.0	27.0	18.0	—	—	—	—
7-13	26	36350870	4.0	7.5	7.5	12.5	2.5	4.0	2.5	7.0	20.0	18.0	16.0	32.0	—	—	—	—
			7.0	12.0	15.0	8.0	<1.0	6.0	2.5	8.5	9.0	30.0	14.0	36.0	—	—	—	—
			5.0	18.0	15.0	16.0	2.0	3.0	4.5	8.0	16.0	25.0	35.0	35.0	—	—	—	—
			9.0	3.0	7.0	1.0	<1.0	2.0	<1.0	23.0	9.0	20.0	8.5	50.0	—	—	—	—
			4.0	8.0	4.0	3.0	3.0	4.0	1.0	4.0	30.0	32.0	10.0	36.0	7.325	4.60	23.70	812.00
			2.0	2.0	7.0	4.0	3.0	<1.0	<1.0	1.0	26.0	10.0	10.0	13.0	—	—	—	—
			3.0	6.0	10.0	12.0	6.0	1.5	20.0	3.0	15.0	10.0	60.0	30.0	—	—	—	—
			12.0	3.5	7.0	9.0	3.0	<1.0	2.5	1.5	23.0	7.0	23.0	12.0	—	—	—	—
			5.0	20.0	14.0	12.0	14.0	20.0	2.5	2.0	62.0	68.0	14.0	15.0	—	—	—	—
			10.0	4.0	6.0	6.0	1.0	1.0	5.0	4.0	13.0	12.0	13.0	42.0	—	—	—	—
7-16	27	41250897	26.0	17.0	6.0	19.0	18.0	3.0	1.0	2.0	35.0	26.0	18.0	19.0	—	—	—	—
			16.0	4.0	23.0	6.0	14.0	3.0	5.0	8.0	46.0	—	27.0	33.0	—	—	—	—
			6.0	5.0	8.0	15.0	3.0	1.0	3.0	2.0	29.0	—	22.0	24.0	—	—	—	—
			2.0	3.0	2.0	8.0	1.5	1.5	1.0	5.5	18.0	—	11.0	31.0	—	—	—	—
			22.0	15.0	5.0	6.0	21.0	2.0	2.0	7.0	65.0	—	21.0	49.0	10.10	6.56	29.80	—
			15.0	19.0	8.0	4.0	5.5	29.0	7.0	8.0	26.0	—	34.0	40.0	—	—	—	—
			12.0	4.0	9.0	6.0	2.0	12.0	6.0	2.0	19.0	—	35.0	22.0	—	—	—	—
			4.0	6.0	3.0	12.0	12.0	3.5	5.0	1.5	48.0	—	23.0	19.0	—	—	—	—
			6.0	14.0	21.0	14.0	2.0	2.0	9.0	17.0	21.0	—	54.0	35.0	—	—	—	—
			6.0	11.0	8.0	9.0	26.0	3.5	2.5	2.5	38.0	—	19.0	14.0	—	—	—	—
	28	40320852	6.0	8.0	1.0	3.0	7.0	12.0	1.0	1.0	14.0	35.0	19.0	17.0	—	—	—	—
			4.0	6.0	5.0	8.0	9.0	25.0	1.5	7.0	42.0	21.0	17.0	42.0	—	—	—	—
			3.0	5.0	4.0	5.0	3.0	6.0	1.0	1.0	51.0	56.0	18.0	15.0	—	—	—	—
			2.0	11.0	5.0	9.0	1.0	15.0	2.0	9.0	12.0	14.0	18.0	42.0	—	—	—	—
			12.0	5.0	15.0	6.0	4.0	1.0	9.0	8.0	26.0	9.0	41.0	53.0	—	—	—	—
			3.0	3.0	2.0	4.0	<1.0	35.0	1.0	1.5	8.0	26.0	13.0	16.0	6.35	4.50	25.00	—
			5.0	4.0	6.0	13.0	6.0	1.0	1.0	1.0	39.0	7.0	12.0	17.0	—	—	—	—
			12.0	3.0	4.0	8.0	9.5	7.5	4.5	<1.0	46.0	46.0	31.0	13.0	—	—	—	—
			6.0	13.0	12.0	14.0	1.0	2.0	1.0	1.0	9.0	33.0	17.0	13.0	—	—	—	—
			5.0	3.0	6.0	5.0	9.5	1.5	1.5	<1.0	43.0	16.0	21.0	12.0	—	—	—	—

Table D-5 (concluded)

Date	Site No.	Grid Coordinates	Stem Spacing, Quadrant (ft) 1	2	3	4	Stem Diameter, Quadrant (in) 1	2	3	4	Stem Height, Quadrant (ft) 1	2	3	4	Average Stem Spacing, (ft)	Average Stem Diameter, (in)	Average Stem Height, (in)	Density (stems/acre)
7-17	29	42260908	2.0	1.0	8.0	3.0	2.5	8.0	1.5	1.0	32.0	30.0	10.0	7.5	—	—	—	—
			6.0	2.5	5.0	5.5	3.0	<1.0	<1.0	1.0	20.0	6.0	6.5	12.0	—	—	—	—
			0.5	8.0	13.0	7.0	95.0	2.5	1.5	1.0	50.0	21.0	12.0	7.0	—	—	—	—
			1.0	2.5	1.5	1.5	25.0	1.0	1.0	1.5	28.0	9.0	9.0	18.0	—	—	—	—
			6.5	7.0	3.0	5.0	1.5	<1.0	1.0	1.5	22.0	6.0	10.0	12.0	6.15	3.60	20.70	—
			1.0	2.0	9.0	4.0	6.0	3.0	7.0	5.0	32.0	20.0	42.0	27.0	—	—	—	—
			6.0	4.0	7.0	9.0	3.0	4.0	4.0	4.5	26.0	22.0	22.0	31.0	—	—	—	—
			1.5	10.0	1.0	1.5	5.0	2.0	3.0	1.5	33.0	20.0	26.0	18.0	—	—	—	—
			6.0	1.0	8.0	15.0	<1.0	3.0	1.0	3.0	18.0	17.0	15.0	22.0	—	—	—	—
			1.0	8.0	6.0	6.0	1.5	1.0	2.5	1.0	12.0	14.0	18.0	9.0	—	—	—	—
7-18	30	40480985	9.0	7.0	1.0	5.0	4.0	16.0	3.0	4.0	33.0	44.0	19.0	32.0	—	—	—	—
			5.0	3.0	4.0	5.0	2.5	<1.0	1.0	1.0	16.0	11.0	12.0	8.0	—	—	—	—
			1.0	4.0	15.0	12.0	1.0	1.0	20.0	5.0	9.0	12.0	41.0	34.0	—	—	—	—
			8.0	3.0	2.0	5.0	2.0	1.0	3.5	<1.0	20.0	11.0	16.0	7.0	—	—	—	—
			2.0	2.0	27.0	5.0	2.0	1.0	5.0	<1.0	19.0	9.0	31.0	7.0	5.70	3.61	18.90	—
			4.0	6.0	3.0	1.0	9.0	1.0	1.0	<1.0	37.0	16.0	12.0	8.0	—	—	—	—
			5.0	6.0	4.0	10.0	1.0	12.0	1.0	<1.0	11.0	47.0	12.0	5.0	—	—	—	—
			4.0	4.0	8.0	1.0	1.5	1.0	12.0	<1.0	14.0	12.0	52.0	6.0	—	—	—	—
			1.0	2.0	1.0	7.0	<1.0	<1.0	1.0	2.0	7.0	11.0	14.0	19.0	—	—	—	—
			12.0	9.0	11.0	5.0	16.0	1.0	3.0	<1.0	36.0	18.0	22.0	7.0	—	—	—	—
7-18	31	40580937	5.0	9.0	3.0	4.0	2.0	1.0	7.0	<1.0	12.0	11.0	22.0	6.0	—	—	—	—
			5.0	1.0	1.0	2.0	15.0	1.0	1.0	1.0	53.0	11.0	13.0	7.0	—	—	—	—
			6.0	4.0	3.0	4.0	1 0	3.0	2.0	1.0	12.0	21.0	14.0	15.0	—	—	—	—
			12.0	12.0	14.0	3.0	3.0	1.0	2.0	2.0	21.0	16.0	7.0	12.0	—	—	—	—
			3.0	4.0	3.0	7.0	5.0	1.0	1.0	3.0	38.0	8.0	19.0	23.0	4.60	2.69	17.50	2,058.00
			7.0	1.0	5.0	6.0	<1.0	<1.0	4.0	<1.0	6.0	7.0	26.0	5.0	—	—	—	—
			4.0	3.0	1.0	5.0	<1.0	2.0	3.0	1.5	8.0	13.0	19.0	14.0	—	—	—	—
			4.0	2.0	6.0	4.0	3.0	4.0	2.0	7.0	36.0	22.0	18.0	48.0	—	—	—	—
			8.0	6.0	1.0	2.0	<1.0	6.0	1.0	<1.0	5.0	42.0	11.0	9.0	—	—	—	—
			3.0	1.0	5.0	4.0	1.0	<1.0	4.0	8.0	5.0	7.0	21.0	37.0	—	—	—	—

APPENDIX E. TERRAIN FACTOR MAP PORTFOLIO

The Terrain Factor Maps are not part of this report but can be requested from USATTC by authorized agencies.

APPENDIX F. PHOTOGRAPHS OF DATA SITES

Figure F-1. Site 1 Looking North.

Figure F-2. Site 2 Looking North.

Figure F-3. Site 3 Looking South.

Figure F-4. Site 4 Looking West.

Figure F-5. Site 5 Looking East.

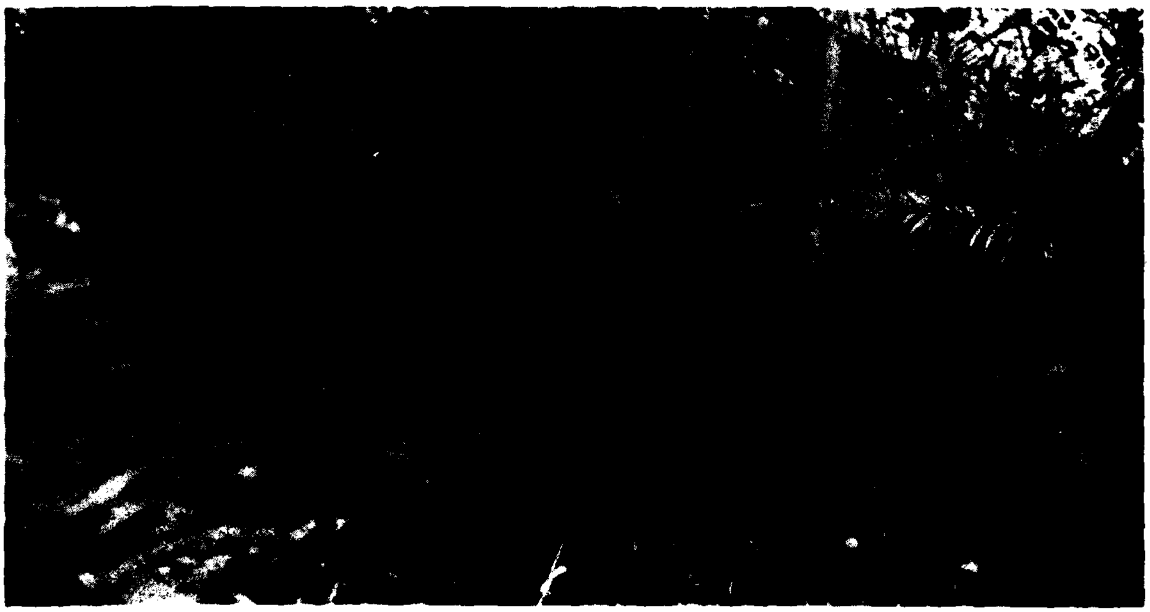

Figure F-6. Site 6 Looking West.

Figure F-7. Site 7 Looking North.

Figure F-8. Site 8 Looking South.

Figure F-9. Site 9 Looking South.

Figure F-10. Site 10 Looking South.

Figure F-11. Site 11 Looking North.

Figure F-12. Site 12 Looking West.

Figure F-13. Site 13 Looking West.

Figure F-14. Site 14 Looking West.

Figure F-15. Site 15 Looking North.

Figure F-16. Site 16 Looking South.

Figure F-17. Site 17 Looking West.

Figure F-18. Site 18 Looking East.

Figure F-19. Site 19 Looking West.

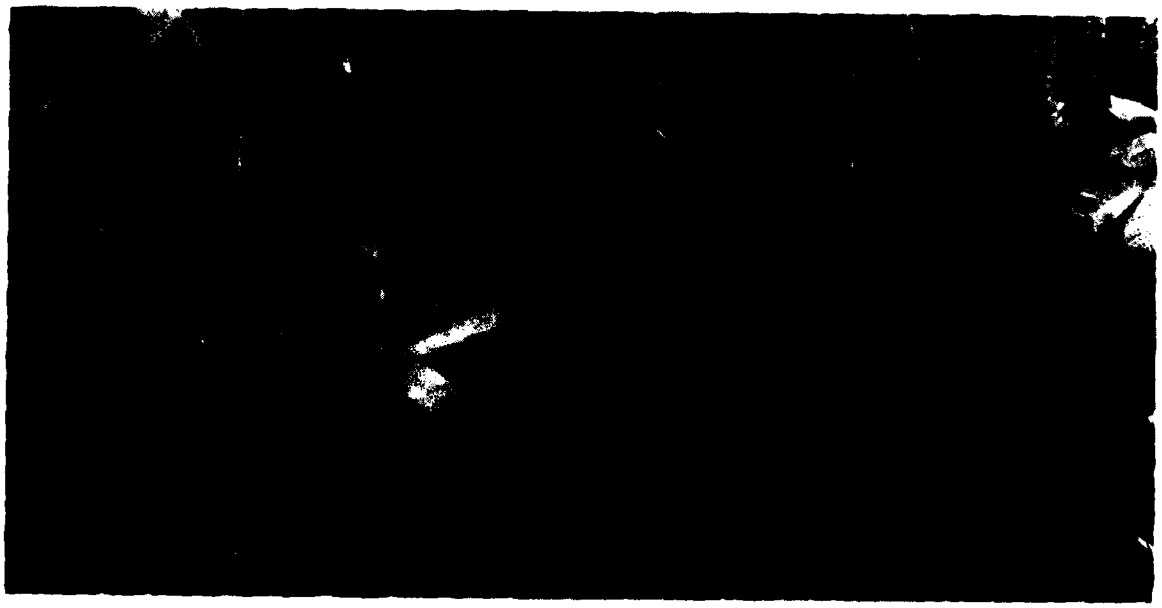

Figure F-20. Site 20 Looking North.

Figure F-21. Site 21 Looking North.

Figure F-22. Site 22 Looking North.

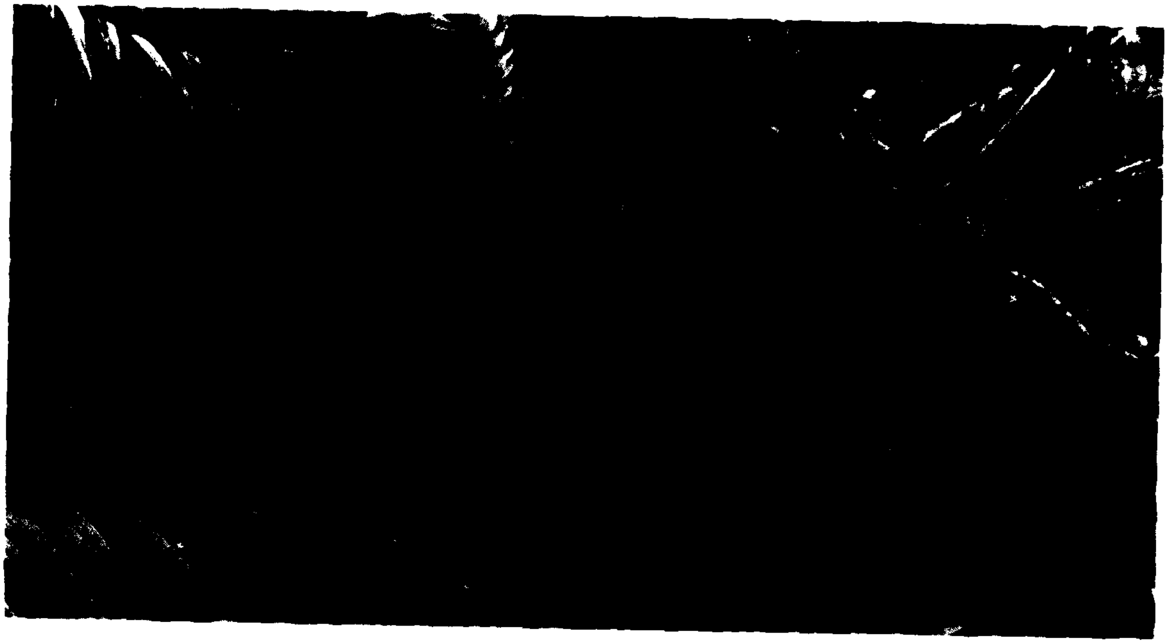

Figure F-23. Site 23 Looking East.

Figure F-24. Site 24 Looking North.

Figure F-25. Site 25 Looking North.

Figure F-26. Site 26 Looking North.

Figure F-27. Site 27 Looking West.

Figure F-28. Site 28 Looking East.

Figure F-29. Site 29 Looking South.

Figure F-30. Site 30 Looking North.

Figure F-31. Site 31 Looking North.

APPENDIX G. SYMBOLS

Surface Composition

USDA Textural Classes

C - Clay
SiC - Silty Clay
SiCL - Silty Clay Loam
CL - Clay Loam
Si - Silt
SiL - Silt Loam
L - Loam
SC - Sandy Clay
SCL - Sandy Clay Loam
SL - Sandy Loam
LS - Loamy Sand
S - Sand

Fine-Grained USCS Soil Types and Sands with Fines

SM - Silty Sands, Sand-silt mixture
SC - Clayey Sands, Sand-clay mixture
ML - Inorganic Silts
CL - Inorganic Clays of low to medium plasticity
OL - Organic Silts and organic silty clays of low plasticity
MH - Inorganic silts, elastic silts
CH - Inorganic Clays of high plasticity, fat clays
OH - Organic clays of high plasticity, organic silts

Others

MC - Moisture Content
LL - Liquid Limit
PL - Plastic Limit
PI - Plastic Index

Soil Strength

CI - Cone Index
RI - Remolding Index
RCI - Rating Cone Index
DBP - Drawbar Pull
τ - Shear Stress
δ - Normal Stress
C_i - Initial Cohesion
C_r - Residual Cohesion
$\emptyset_i$ - Initial Angle of Internal Friction
$\emptyset_r$ - Residual Angle of Internal Friction

Surface Geometry

BF - Bottomland Flat
LT - Lower Terrace
UT - Upper Terrace
LS - Lower Slope
MS - Middle Slope
US - Upper Slope
UF - Upland Flat
Sd - Standard Deviation of Sample
$\bar{x}$ - Mean
N - Number of Data Points
L - Length
W - Width
H - Height
AA - Approach Angle

Vegetation

NND - Nearest Neighbor Distance between trees
DBH - Diameter of a tree at Breast Height, 4.5 ft.
SD - Stem Density
A - Unit Area

Structural Cell

SC - Stem Spacing
Dc - Diameter of expanded cell
Wt - Total Work to override single stem
d_s - Stem Diameter

APPENDIX H. REFERENCES

1. Bennett, H. H., Soil Reconnaisance of the Panama Canal Zone and Contiguous Territory; US Department of Agriculture, Test Bulletin No. 94, January 1929.

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