US Army Corps of Engineers

ENVIRONMENTAL LABORATORY

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DUST AND EROSION CONTROL METHODS FOR US ARMY CONSTRUCTION PROJECTS IN HONDURAS

by

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Environmental Laboratory

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Dust	Soil fertility	Wind
Erosion	Surface-water runoff	Windbreak

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

A joint US/Honduran venture to develop the infrastructure of Honduras includes the construction of several roads and airfields in various parts of the country. Erosion on roadway slopes and banks has led to road failures. Exposed soils along airfields are subject to erosion by natural and aircraft-generated winds, creating hazardous conditions for aviators and increased maintenance costs. US Army Engineer Waterways Experiment Station (WES) personnel traveled to Honduras to investigate and provide recommendations to correct the problems at four construction projects: a road-construction project (Fuertes Caminos Road), one airbase (Joint Task Force (JTF) Bravo/Palmerola), and two airfields (San Lorenzo Airfield and Jamastran Airfield). These projects are located in four different areas of Honduras.

WES personnel noted road and slope failures as the result of unchecked surface-water runoff on Fuertes Caminos Road. Accurate estimates of surface-water runoff during storm

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events and the use of improved water diversion and control techniques are needed to reduce the destructive effects. Improved vegetation on roadway slopes and embankments can reduce the effects of surface-water runoff and can be accomplished through proper soil preparation and plant selection. Analysis of soil samples taken by WES investigators indicated that liming and the addition of nitrogen, phosphorous, and sulfur fertilizers are necessary for good plant growth.

Dust is the major problem at JTF Bravo/Palmerola. Frequent winds and aircraft activity coupled with inadequate vegetation or the complete lack of vegetation cause erosion of the soil. Improving soil fertility and establishing an aggressive sod-forming grass will greatly reduce the effects of wind erosion. Soil samples indicated that nitrogen and phosphorous fertilizers are needed; however, lime is not. WES personnel also recommend the establishment of tree windbreaks to reduce the impacts of the high winds prevalent in the area.

The San Lorenzo Airfield is located in a very arid climate and is void of vegetation. Establishment of vegetation by seed can be accomplished during the rainy season by proper seedbed preparation and by using a hydro-mulcher with humectant compound. Nitrogen, phosphorous, and sulfur fertilizers are needed to improve the soil fertility. Because of the harsh climate, WES investigators recommend the establishment of small test plots to determine the plant species most adaptable to the area prior to widespread planting operations. Tree windbreaks may also be considered to reduce wind effects.

The lack of vegetative cover at Jamastran Airfield was not as severe as at San Lorenzo Airfield. However, improvement of existing vegetation is needed to reduce dust problems. The introduction of superior species of vegetation without destruction of existing vegetation can be accomplished by applying seed with a hydro-mulcher. Only nitrogen is required to improve soil fertility at Jamastran Airfield. Tree windbreaks are also recommended for Jamastran Airfield.

The drainage engineering and agronomic techniques discussed in this report will greatly help to reduce soil erosion caused by surface-water runoff and wind. Agronomic techniques can be long-term solutions if care is taken to properly maintain the vegetation. Maintenance will be site-specific and may include periodic fertilization, mowing, burning, and grazing. Soil sampling will be necessary every 3 years to determine lime and additional fertilizer needs.

PREFACE

This study was conducted by the Environmental Laboratory (EL) of the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, during 1988 for the Commander, US Army South, Miami, FL. The objectives of this study were to determine dust and erosion control measures that could be implemented at US Army Engineer construction projects in Honduras.

The study was conducted by personnel of the Contaminant Mobility Team (CMT) of the Contaminant Mobility and Regulatory Criteria Group (CMRCG), Ecosystem Research and Simulation Division (ERSD), EL. The CMT is composed of Dr. Bobby L. Folsom, Jr., Team Leader; Dr. Judith C. Pennington; CPT Todd R. Higgins; Mr. Richard A. Price; Ms. Donna R. Garrett; Ms. Carole P. Brown; Ms. Brenda K. Allen; Ms. Joycie R. Bright; and Mr. Mark B. Cooper. This report was written by CPT Higgins and Mr. Price. The study was under the general supervision of Dr. Lloyd R. Saunders, Chief, CMRCG; Mr. Donald L. Robey, Chief, ERSD; and Dr. John Harrison, Chief, EL. This report was edited by Ms. Lee T. Byrne of the Information Technology Laboratory.

COL Dwayne G. Lee, EN, is the Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

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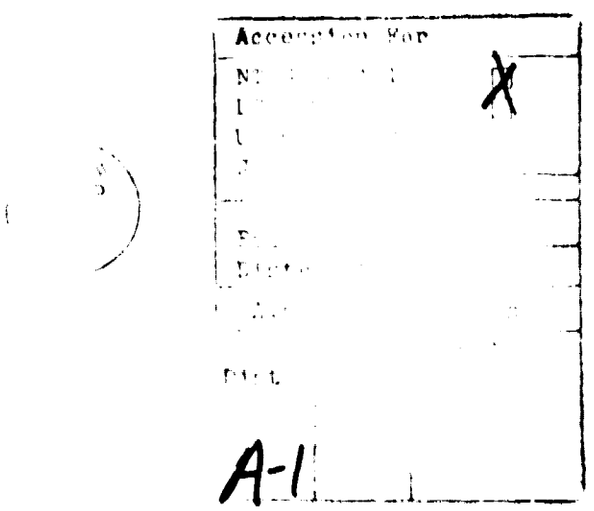

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic feet	0.02831685	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or kelvins*
feet	0.3048	metres
gallons	3.785412	cubic decimetres
inches	25.4	millimetres
miles (US statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms
square miles	2.589998	square kilometres
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C + (5/9) (F - 32). To obtain kelvin (K) readings, use K + (5/9) (F - 32) = 273.15.

DUST AND EROSION CONTROL METHODS FOR US ARMY CONSTRUCTION PROJECTS IN HONDURAS

PART I: INTRODUCTION

Background

1. The US Army, Army Reserve, and Army National Guard Engineer units are involved in a joint US/Honduran venture to develop the infrastructure of Honduras. As part of the venture, several roads and airfields are being constructed. This construction has led to improved commerce in several areas of the country, but has also produced dust and erosion problems. Dust on roadways impairs driver visibility and can create serious safety hazards. Erosion of banks and slopes by runoff water has led to roadway failures. Exposed soils on or adjacent to runways are susceptible to erosion from wind and rotor- or propwash, creating hazardous conditions for aviators and increasing aircraft maintenance costs. The problem is to control dust and to reduce or eliminate the erosive effects of runoff economically while using assets available in-country.

Description of the Country

2. Honduras is one of the northernmost countries in Central America, bordered on the north and east by the Caribbean Sea, the south by Nicaragua, and the west by El Salvador and Guatemala. There are approximately 2.6 million inhabitants dispersed over 44,402 square miles.* Over 10 percent of the population lives in and around the capital city of Tegucigalpa. The major cities are connected by a modern, well-maintained road network. There are several seaports along the Caribbean coast, but only one port of significance has direct access to the Pacific Ocean. Railroads are limited to the northwestern region of the country and are used primarily to transport fruit to the coastal ports for export.

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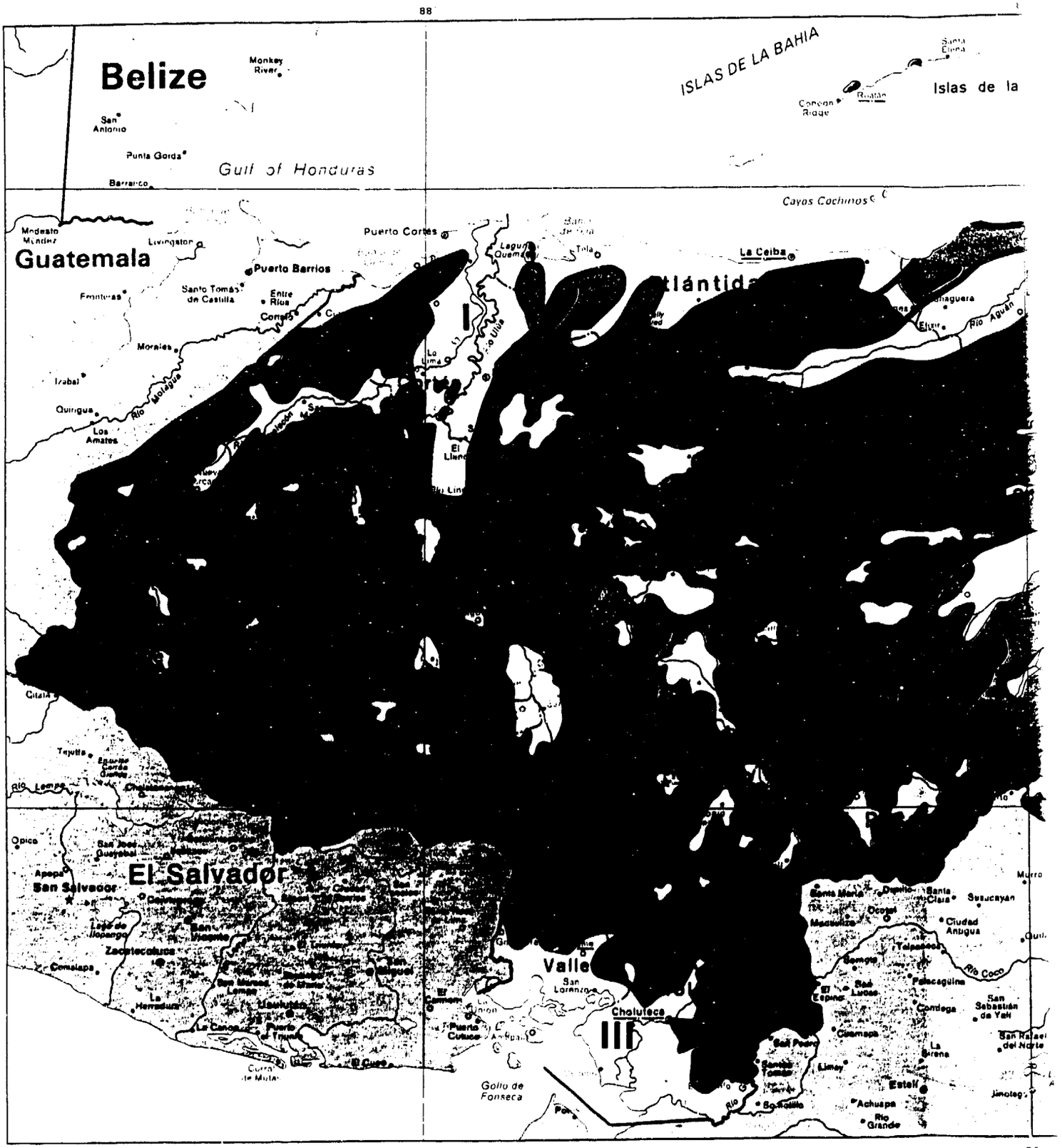
* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

3. There is little industry in the country other than that required to support agriculture. Manual labor is plentiful and is employed to a large extent throughout the country. Very few farms are sufficiently large to require mechanization. Farms that are mechanized still rely heavily on manual labor to perform most tasks. Bananas, pineapples, and papayas are the predominate crops. Sugarcane, corn, and other grains are grown in the intermountain valleys. Cotton is grown in some of the more arid regions of the country, such as near San Lorenzo. Large-scale vegetable farming is found near the cities, but exists at the subsistence level throughout the country. Honduras boasts a large cattle population. Most of the cattle industry is beef; however, sizable dairy herds located near the major cities supply fluid milk. Poultry and swine production is also found throughout the nation.

4. The topography of Honduras is varied, with nearly 80 percent of the country located in mountainous terrain (Figure 1). The following three major landform divisions have been identified: the Interior Highlands, the Caribbean Lowlands, and the Pacific Lowlands. The Interior Highlands consist of two mountain chains: the Central American Cordillera to the north and the Volcanic Highlands to the south. The highest peaks occur in the western region of the country and range in height from 7,875 to 9,186 ft (Figure 2). Elevations range from 1,476 to 7,875 ft in the lower mountains. The highest peaks have very steep slopes, some exceeding 100 percent; however, more typical slopes range from 35 to 45 percent in the lower mountains and 10 to 30 percent in the intermontane basins and plateaus. The Pacific Lowland is a narrow strip of coastal plains bordering the Gulf of Fonseca. Most of the area consists of flat or rolling plains with slopes generally not exceeding 3 percent. The Fuertes Caminos Road project, Palmerola Airbase, and Jamastran Airfield are located in the Interior Highlands, whereas the airstrip at San Lorenzo is located in the Pacific Lowlands. The Caribbean Lowlands extend east to west along the northern coast of the country and throughout much of the Gracias a Dios department. The terrain is flat and rolling with few slopes exceeding 2 percent. Many areas of the region have elevations that barely exceed sea level. None of the construction projects discussed in this report are located in the Caribbean Lowlands region of the country.

5. The vegetation in Honduras can be categorized into one of four major types of ecosystems: forest, savanna, mangrove, and cultivated cropland (Figure 3). Nearly 45 percent of the country is covered by forest. Grass and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Monkey River
San Antonio
Punta Gorda
Gulf of Honduras
Barranco
ISLAS DE LA BAHIA
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Cayos Cochinos
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Cuyutlán
Valle
San Lorenzo
Cholutteca
Golfo de Fonseca
Corinto
Puerto Cortés
Omoa
Murro
Santa María
Ocotal
Santa Clara
Susucayán
Ciudad Antigua
Talpaseca
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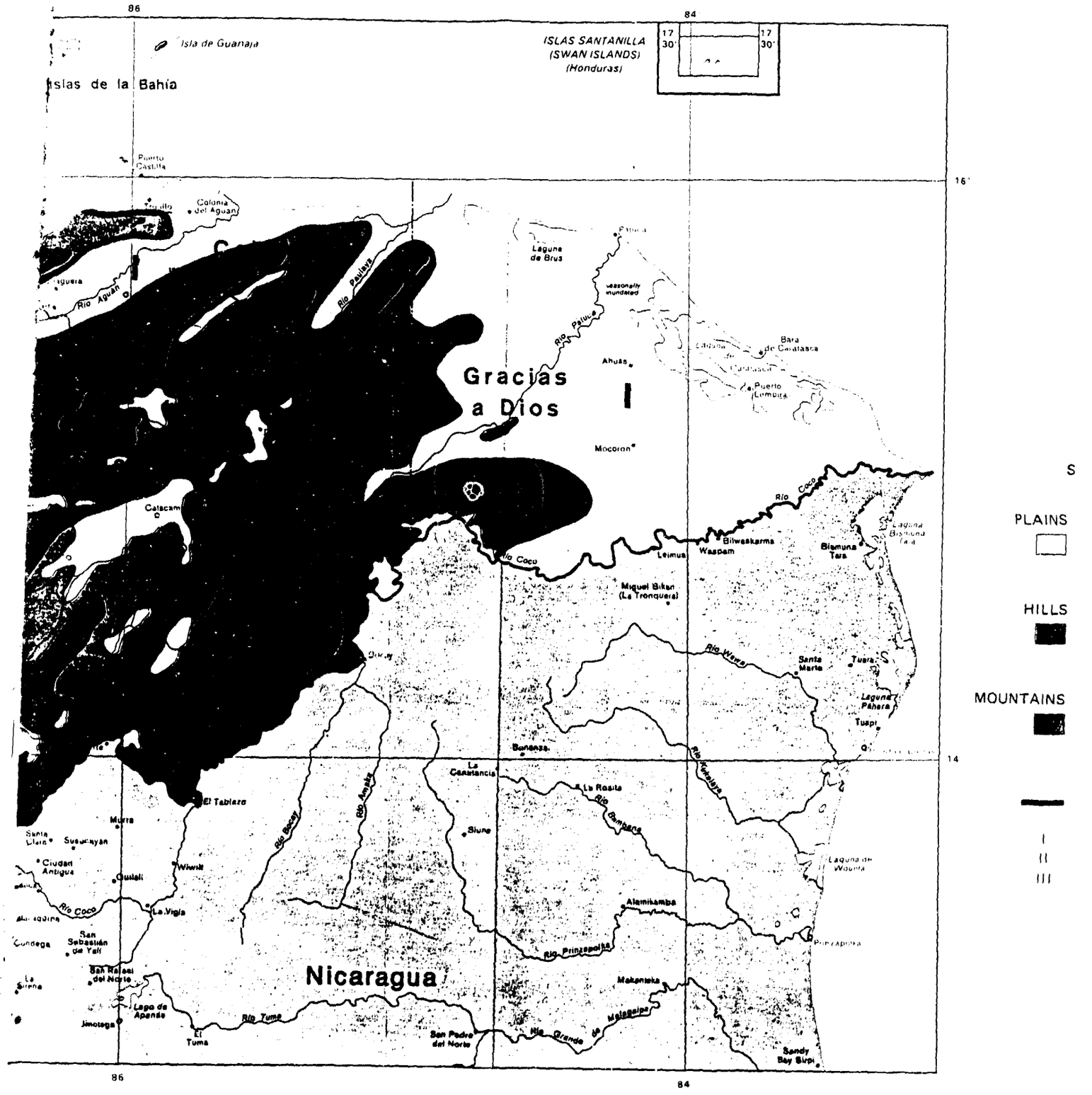
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Isla de Guanaja
Islas de la Bahia
ISLAS SANTANILLA
(SWAN ISLANDS)
(Honduras)
17 30'
17 30'
Puerto Castilla
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Río Paulaya
Río Patuca
Bara de Cartiasca
Ahuas
Gracias a Dios
Puerto Lempira
Mocoron
Río Coco
Leimus
Bilwaskarma
Waspam
Biamuna Tara
Laguna Biamuna
Miguel Bikan (La Tronquera)
Río Wawa
Santa Marta
Tuara
Laguna Pahara
Tuspi
Bonanza
La Constancia
La Rosita
Río Kukalaya
Río Bambana
El Tablazo
Río Escalí
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HONDURAS

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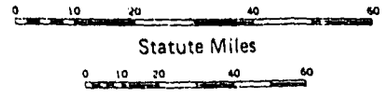


SURFACE CONFIGURATION

CONFIGURACION DE LA SUPERFICIE

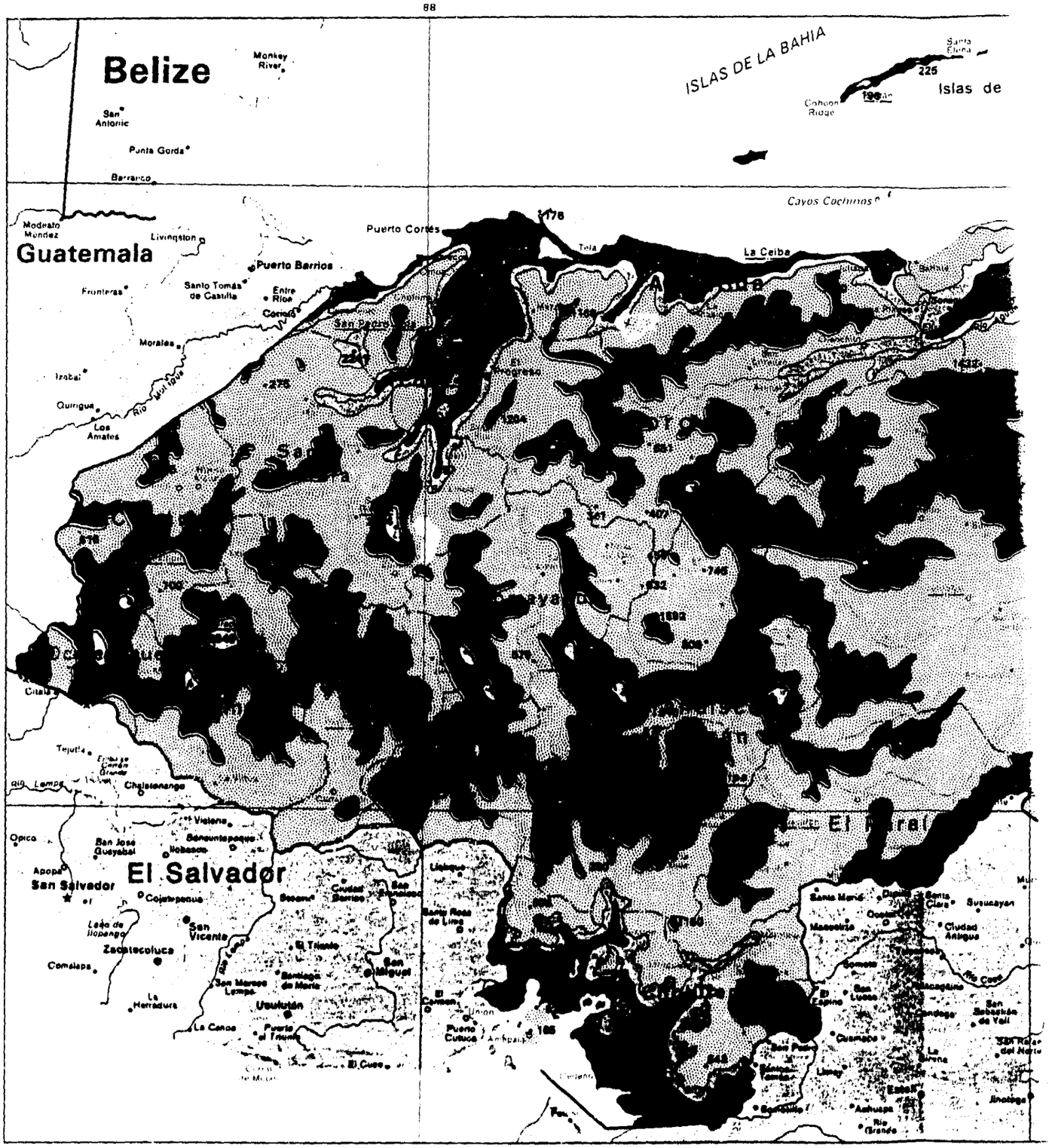
PLAINS	Difference between highest parts of interstream areas and adjacent valley bottoms generally less than 150 m. Most slopes less than 10 %.	*ILLANURAS*	*La diferencia entre las partes mas altas de las ondulaciones y las partes mas bajas de valles adyacentes, generalmente menor de 150 m. La mayor parte de las pendientes menores del 10%.*
HILLS	Difference between tops of hills and adjacent valley bottoms generally between 150 m and 600 m. Most slopes between 10% and 30%.	*CERROS*	*La diferencia entre la cima de los cerros y las partes mas bajas del valle adyacente, generalmente entre 150 y 600 m. La mayoria de las pendientes entre 10% y 30%.*
MOUNTAINS	Difference between crests of mountains and adjacent valley bottoms generally more than 600 m. Most slopes between 30% and 45%; higher crests generally exceed 45%.	*MONTANAS*	*La diferencia entre la cuspide de las montanas y la parte mas baja del valle adyacente, generalmente de mas de 600 m. La mayoria de las pendientes entre 30% y 45%; las cimas mas altas generalmente exceden el 45%.*

LANDFORM DIVISIONS

DIVISIONES DE FORMACIONES TERRESTRES

I	Caribbean Lowlands	*Tierras bajas del interior*
II	Interior Highlands	*Tierras altas del interior*
III	Pacific Lowlands	*Tierras bajas del Pacifico*

Figure 1. Surface features comprising Honduran topography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Tela
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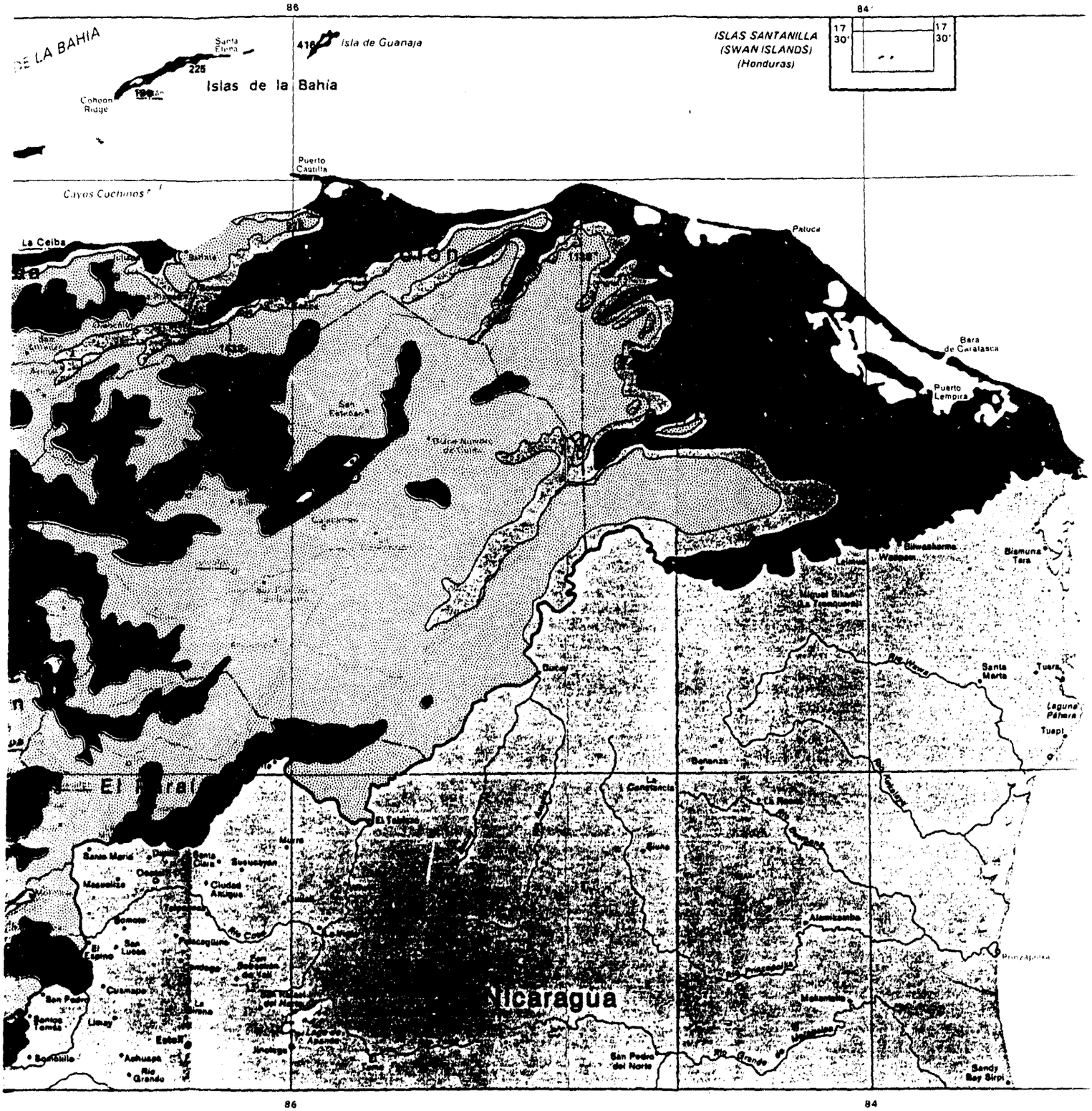
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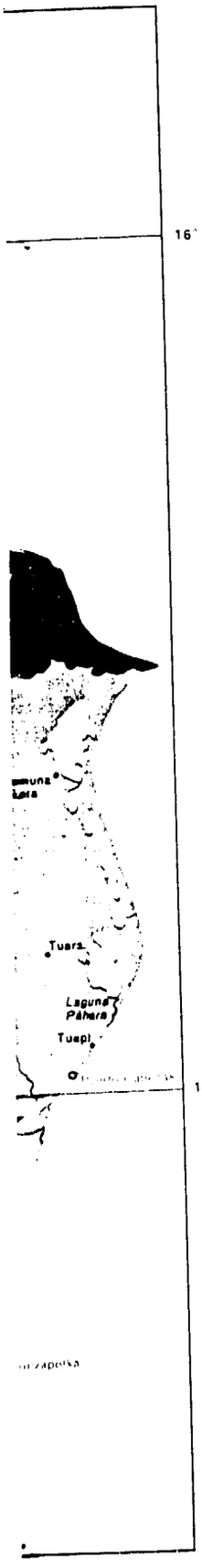


HONDURAS

Scale 1:1,500,000

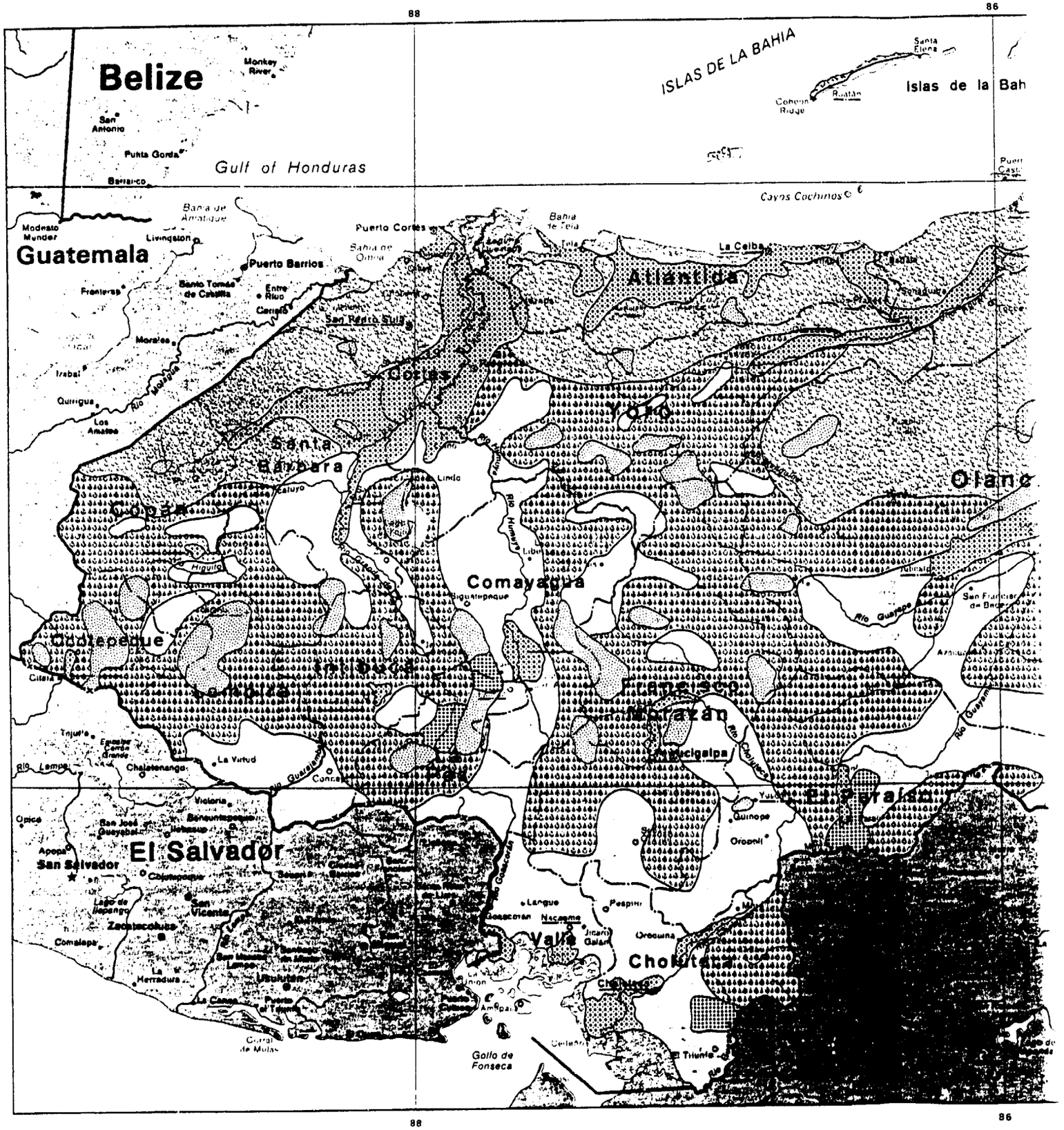
0 10 20 40 60

Statute Miles

0 10 20 40 60

Kilometers

ELEVATIONS	*ELEVACIONES*
2200 to 3000 m	*2200 a 3000 m*
1000 to 2200 m	*1000 a 2200 m*
200 to 1000 m	*200 a 1000 m*
100 to 200 m	*100 a 200 m*
0 to 100 m	*De 0 a 100 m*
1200. Spot heights is meters	*Cotas de metros*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Bahía de Amatique
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Bahía de Omoa
Bahía de Tela
La Ceiba
Puerto Barrios
Santo Tomás de Castilla
Entre Ríos
Frontera
Morales
Izabal
Quiriguá
Los Amates
Río Motagua
San Pedro Sula
Atlántida
Cortés
Yoro
Santa Bárbara
Olanc
Copán
Comayagua
Ocotepeque
Intibucá
La Paz
Lempira
Francisco Morazán
El Paraíso
Choluteca
Valle
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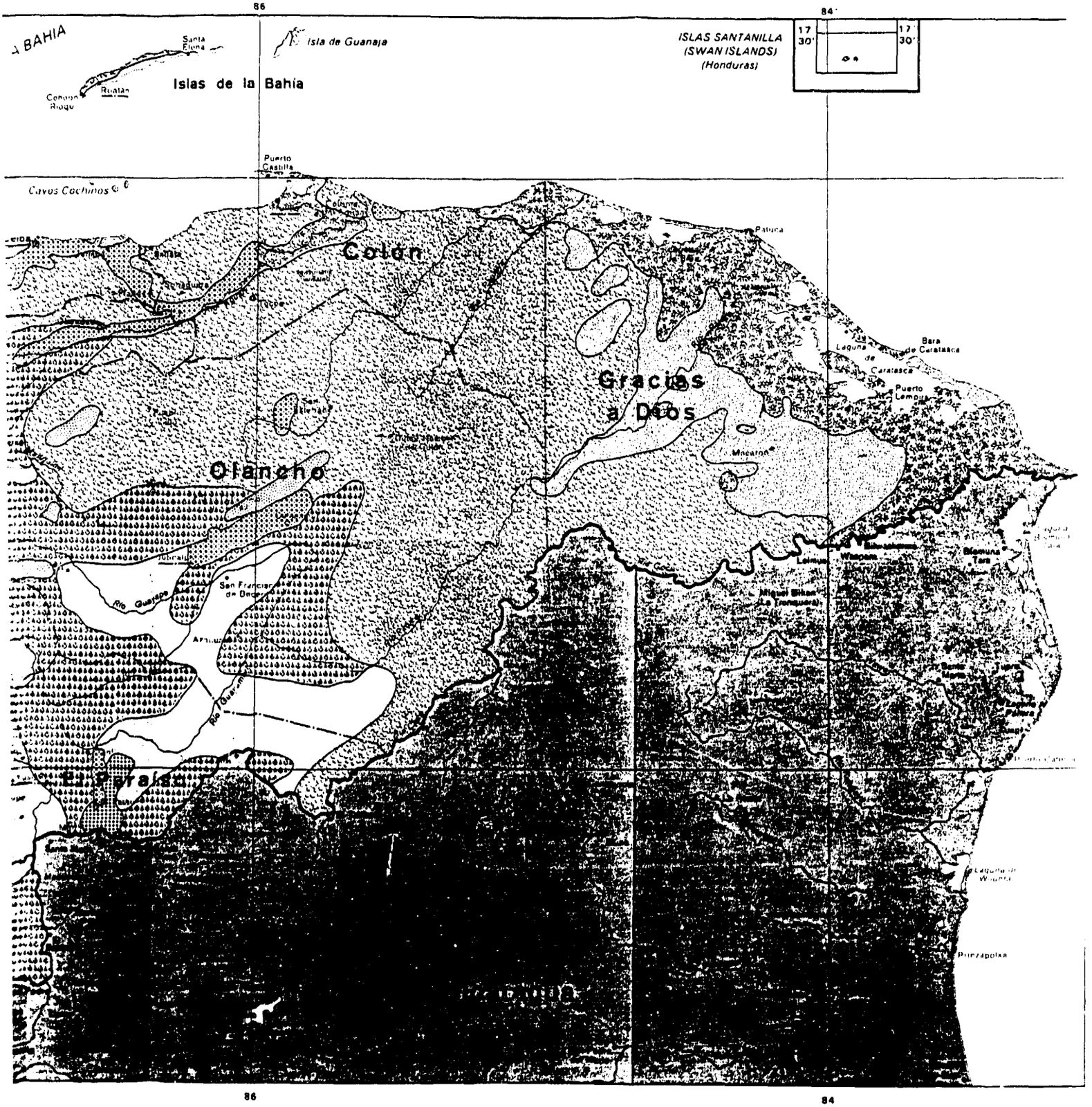
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Cayos Cochinos
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Gracias a Dios
Olancho
Río Guayape
San Francisco de Becerra
Río Guayape
Patuca
Laguna de Caratasca
Bara de Caratasca
Puerto Lempira
Mocorón
Prinzapolka
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HONDURAS

Scale 1:1,500,000

0 10 20 40 60

Statute Miles

0 10 20 40 60

Kilometers

VEGETATION	*VEGETACION*
FOREST	*BOSQUE*
Dense broadleaf evergreen forest; some shifting cultivation	*Bosque denso de hoja ancha simpre verde; algun cultivo transitorio*
Pine and oak; little cultivated vegetation	*Bosque abierto de coniferas siempre verdes y hoja ancha decidua; poco vegetacion cultivada*
Pine and broadleaf evergreen	*Bosque nebuloso de coniferas y de hoja ancha siempre verde*
Deciduous broadleaf forest and scrub; some savanna and cultivated vegetation	*Bosque de hoja ancha decidua y chaparral; alguna y vegetacion cultivada*
GRASS	*PASTO*
Pine savanna	*Sabana de pino*
SWAMP AND MARSH	*PANTANO Y MARISMA*
Mangrove swamp and marsh	*Pantano de mangle y marisma*
CULTIVATED VEGETATION	*VEGETACION CULTIVADA*
Bananas, coffee, sugarcane, corn, cotton, and other crops	*Bananos, cafe, cana de azucar, maiz, algodon, y otras cosechas*
Coffee plantations	*Plantaciones de cafe*

3 of 3

shrub savannas are found in the intermontane basins and valleys and continue to the lower mountain slopes in some regions.

Forest

6. There are four main types of forest in Honduras: broadleaf pine, pine and oak, pine and broadleaf evergreen, and deciduous broadleaf forest and scrub. A brief discussion of each forest type follows.

7. Broadleaf evergreen association. Found in the well-drained soils of the northern and eastern portions of the country, these are multistoried forests that form a dense, continuous canopy. The upper story is dominated by hardwood species such as mahogany, laurel, castilla rubber, rosewood, sweetgum, and guayacan. The lower story is composed of mostly cohune and other palm trees, and the undergrowth consists of spiny palms, bamboo grasses, epiphytes (air plants), shrubs, ferns, and woody vines.

8. Pine and oak association. This association occurs on mountain slopes at elevations of 900 to 1,800 m. It is found predominantly in the central region of Honduras. Stands are open canopy with a mixture of pine and oak at the lower elevations; however, pure stands of pine are often found at higher elevations. The undergrowth consists of sparse shrubs and grass, with solid stands of grass common. Grass fires occur frequently during the latter part of the dry season (March through the beginning of June).

9. Pine and broadleaf evergreen association. This association occurs at elevations above 1,500 m on moist, windward mountain slopes. Species of the pine and broadleaf evergreen association include pine, oak, sweetgum, and laurel.

10. Deciduous broadleaf and scrub association. This association consists of oak and thorn scrubs, which cover many intermontane basins and valleys and some lower slopes of the Interior Highlands. Much of the scrub is secondary growth, a result of the slash and burn agricultural practices common in the past and still practiced throughout the country. Grasslands and cultivated crops are often found in the valleys and basins after the removal of the scrub.

Savanna

11. The savanna is found on the porous, gravelly soils of the eastern Caribbean Lowlands. The vegetation consists of pine and palmetto trees dispersed among tall grasses and sedges. This area is extremely susceptible to fire during the dry season.

Mangrove swamps

12. Mangrove swamps are found extensively along the Pacific and Caribbean coasts and can be found further inland along brackish streams. Mangrove and palm trees, cattails, grasses, sedges, and floating plants are the dominant species found in the swamps. Pines are commonly found on the fringes of the swamps.

Cultivated cropland

13. Cultivated land can be found throughout the country; however, large tracts of cultivated farmland are concentrated primarily in the Pacific and Caribbean Lowlands. In the Interior Highlands, slash and burn agriculture is practiced with little regard for maintaining soil fertility or preventing soil erosion. Small groves of pineapple and banana trees can be found throughout the Interior Highlands, but fruit plantations are generally found in the Caribbean Lowlands and valleys of the northern Interior Highlands. Coffee plantations are found in the lower elevations of the Interior Highlands on plantations of 10 to 20 ha.

14. Honduras can be divided into the three following climatic regions: tropical wet, tropical dry, and tropical mountain (Figure 4). The climate of each region is unique and exhibits numerous subclimates. The Bermuda high and migratory low-pressure systems dominate the weather of the region.

Tropical wet Caribbean region

15. Dominated by the warm, moist air of the Bermuda high-pressure system, temperatures in this region remain high throughout the year. The mean annual temperature is 27° C, with the warmest months of the year occurring between April and October. Rainfall exceeds 250 cm per year and is distributed throughout the year. Peak rainfall occurs in October and November. Average humidity for the region is 80 percent.

Tropical wet and dry
Pacific/interior regions

16. The climate of this region is marked by a distinct wet and dry season. The dry season occurs from November to May, a period coinciding with the dominance of the northeast tradewinds. The wet season is dominated by a low-pressure system, known as the doldrums, lasting from June to October. Average annual temperatures range from 20° C at interior locations to 30° C in the Pacific Lowlands. Minimum temperatures in the interior regions can approach the freezing mark. The relative humidity averages 77 percent during


88
16
14
Belize
Monkey River
Gulf of Honduras
ISLAS DE LA BAHIA
Islas de
Cayos Cochinos
Guatemala
Livingston
Puerto Barrios
Santo Tomás de Castilla
Entre Ríos
Morales
Izabal
Quirigua
Los Amates
Río Motagua
Puerto Cortés
Bahía de Omoa
Bahía de Tela
Tela
La Ceiba
Olanchito
San Lorenzo
Arenal
Cortés
San Marcos
Santa Bárbara
Santa Rita
El Llano
Río Lindo
Yoro
Copán
Comayagua
La Libertad
Minas de Oro
El Porvenir
Juticalpa
Río Guayape
Ocotepeque
Intibucá
Lempira
Esperanza
Francisco Morazán
Tegucigalpa
Río Jalán
La Paz
El Paraíso
Yuscarán
Tejutla
Río Lempa
Chalatenango
Opico
Apopa
San Salvador
El Salvador
Comalapa
Langue
Nacaome
Pespire
Valle
Orocuina
San Lorenzo
Choluteca
Golfo de Fonseca
El Triunfo
Santa María
Dipilto
Ocotal
Macuelizo
Somoto
San Lucas
El Espino
Cusmapa
Achuapa
Río Grande

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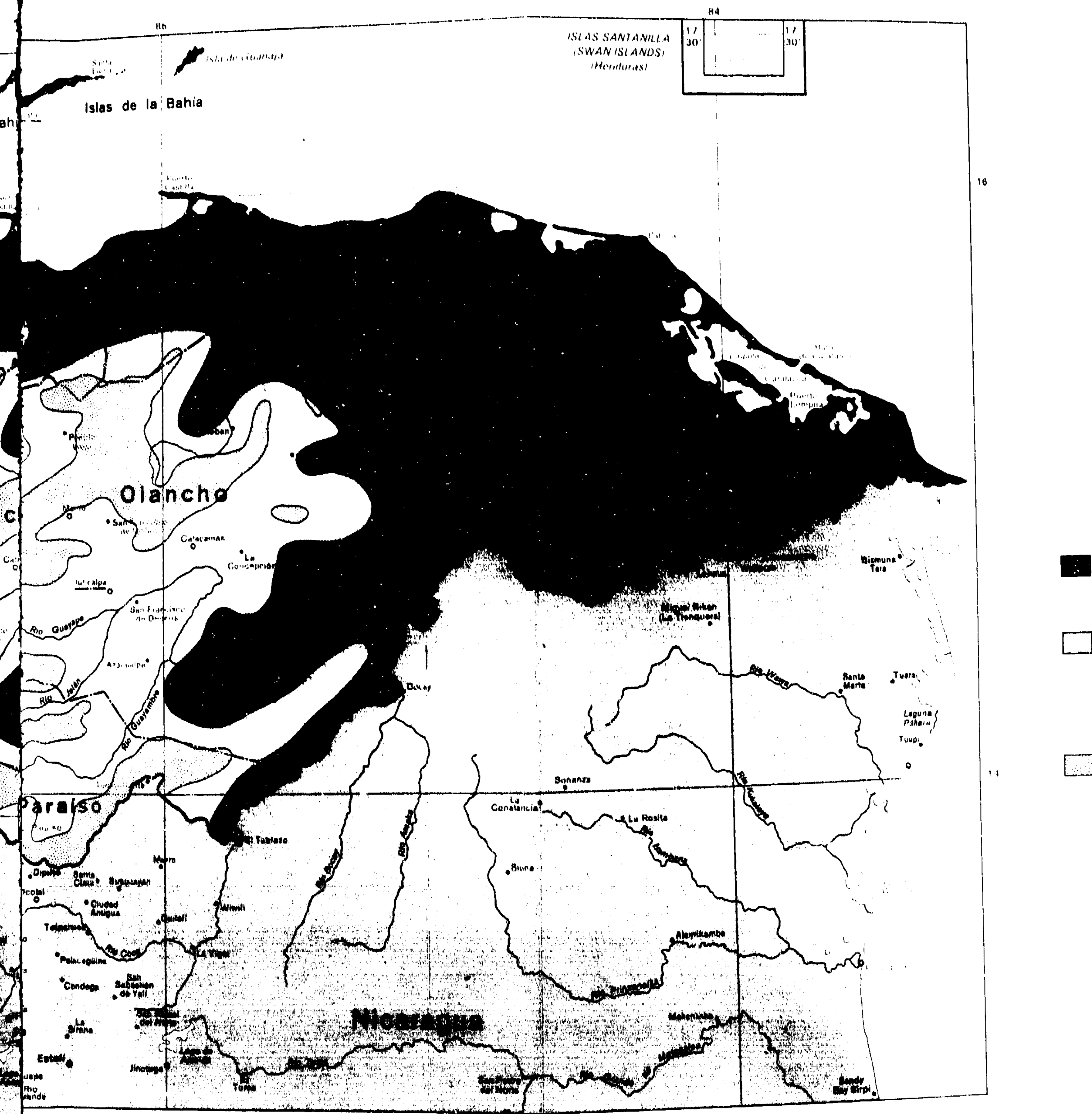
86
84
ISLAS SANTANILLA
(SWAN ISLANDS)
(Honduras)
Islas de la Bahia
16
14
Olancho
Catacamas
La Concepción
Juticalpa
Rio Guayape
Rio Guayambre
Paraíso
Bonanza
La Constancia
La Rosita
Siuna
Alamikamba
Nicaragua
Estelí
Jinotega
Condega
Palacagüina
San Sebastián de Yalí
Ciudad Antigua
Ocotal
Murra
Quilalí
Wiwilí
La Vigía
Miguel Bikan (La Tronquera)
Bismuna Tara
Santa Marta
Tuara
Laguna Pahara
Tuapí
Rio Wawa
San Pedro del Norte
Sandy Bay Sirpi
Makantaka

HONDURAS

Scale 1:1,500,000

0 10 20 40 60

Statute Miles

0 10 20 40 60

Kilometers

16

14

CLIMATIC ZONES

ZONAS CLIMATICAS

TROPICAL WET CLIMATE—Rainfall most of the year; mean temperatures of coolest month above 18°C.

CLIMA TROPICAL LLUVIOSO—Fuerte precipitacion la mayor parte del ano; promedio de temperatura del mes mas fresco, arriba de

TROPICAL WET AND DRY CLIMATE—District dry season during winter with 4 to 6 months with less than 6 cm mean monthly rainfall (usually November—April); rainy season (usually May—October); mean temperature of coolest month above 18°C.

CLIMA TROPICAL LLUVIOSO Y SECO—Marcada estacion seca durante el invierno de 4 a 6 meses, conmenos de 6 cm en promedio, de precipitacion mensual (usualmente noviembre-abril); estacion lluviosa usualmente de mayo a octubre; promedio de temperatura del mes mas fresco arriba de 18°C.

WARM TEMPERATE CLIMATE—Winter dry; at least 10 times as much rain in wettest month of summer as in driest month of winter; mean temperature of coolest month below 18°C, but above −3°C, mean temperature of warmest month over 10°C.

CLIMA TEMPLADO HUMEDO—Invierno seco; por lo menos 10 veces mas lluvia en el mes mas humedo del verano que en el mes mas seco del invierno: promedio de temperatura del mes mas fresco bajo 18°C, pero arriba de −3°C; promedio de temperatura del mes mas caluroso, arriba de 10°C.

Figure 4. Climatic regions of Honduras

the wet season and, with a few exceptions, 60 percent during the drier months. Rainfall along the Pacific Lowlands averages 195 cm, decreasing to 178 cm in the interior portions of the region. Heaviest rainfall occurs in September. Strong winds, often in excess of 70 kph, frequently flow through the Comayagua depression and other interior valleys.

Tropical mountain region

17. The climate of this region is more temperate than tropical in nature. Mean annual temperatures vary with location and altitude, ranging from 16° to 22° C. December and January are the coolest months of the year. Nighttime temperatures during these months can be near freezing. Precipitation is dependent upon exposure; however, between 89 and 178 cm of rain falls annually. The relative humidity of the region ranges from 75 to 85 percent.

Statement of US Policy for Construction Projects in Honduras

18. The Congress of the United States of America has mandated that all US military facilities constructed in Honduras will be temporary. No permanent facilities may be constructed. Furthermore, Honduras must provide the materials required for construction projects not in direct support of US Forces, i.e. culvert pipes for road drainage. The use of plant species to stabilize embankments or reduce dust is not considered permanent construction, but rather an integral component of the project.

Focus

19. This report will focus on using vegetation to reduce erosion on embankments and areas adjacent to roads and airfields. Discussions of bank stabilization, wind break development, and ecosystem development will be included with recommendations of plant species suitable for use in controlling dust or erosion at each construction site of concern. Methods to control dust generated from the surfaces of roadways, airfields, or airfield parking aprons will not be included in this report.

PART II: PREVIOUS EROSION CONTROL RECOMMENDATIONS

20. During October 1986, Mr. Ronald Pecoff of Pecoff Brothers Nursery and Seed, Inc., made an inspection trip to Honduras under contract to the US Army for the purpose of developing dust and erosion control recommendations. His recommendations were submitted to the Deputy Chief of Staff, Engineering, US Army South in November 1986. US Army Engineer Waterways Experiment Station (WES) personnel reviewed these recommendations from the perspective of cost effectiveness, suitability, ease and timeliness of vegetation establishment, and conformity with current regional land use.

21. The philosophy used by Mr. Pecoff in developing his recommendations appears to have been one of creating a diversified ecosystem, representative of the indigenous flora and designed to provide the erosion control properties required by the US Army. WES personnel consider this philosophy to be worthy of consideration and applicable to a number of areas. They do not believe that the development of a diversified ecosystem is the best approach to all areas of concern. The development of a diversified ecosystem requires time because rapidly growing plants are eventually succeeded by more dominant, slower growing plants, such as trees. Succession continues until a climax forest is reached. On the other hand, a monoculture may provide the erosion protection and longevity required at a lower cost of establishment. The ideal solution probably lies between monoculture and a truly diversified ecosystem.

22. The recommendations made by Mr. Pecoff were based on the assumption that seed mixtures would be sown using a hydro-seeder. This assumption influenced components of the seed mixture; i.e., species were selected for compatibility with each other. For example, the tree species included in the seed mixture influenced the selection of grass species selected. If the recommended tree and shrub species could be obtained as nursery plants instead of as seed, a more aggressive grass species could be used in the initial seeding. WES personnel believe that nursery plants are available in Honduras and inexpensive labor is readily available to plant the seedlings. Grass species are also available that can be sprigged and established very rapidly to form a sod, providing excellent erosion protection. An advantage of the hydro-seeding, as recommended by Mr. Pecoff, is that vegetative cover can be established during the dry season. Dry season establishment can be performed provided that the additives he recommended are used and if resources are

available for applying water to the emerging vegetation. The WES premise is that resources are scarce and that watering equipment will be required for the construction effort and will not be available for watering vegetation. WES personnel further assume that because of the nonavailability of resources and watering equipment, vegetation establishment will be accomplished at the beginning of the wet season.

23. The logistical implications of Mr. Pecoff's recommendations need to scrutinized. A Bowie 500-gal hydro-mulcher has been purchased and is currently at Joint Task Force (JTF) Bravo, Palmerola, Honduras. The cost of shipping seed, fiber mulch, humectant, lime, and fertilizer to Honduras may be prohibitively expensive. Ocean shipping is probably the most cost-effective means of transporting these materials in the quantities required. The use of sawdust as an alternative mulching material in the hydro-mulcher was considered when WES personnel viewed the large quantities of sawdust at sawmills located near several of the construction sites. They questioned a representative of the Bowie Company about the use of sawdust as a mulching material. The sawdust may contain allelopathic compounds that may inhibit seed germination or seedling growth. The sawdust is so fine that it tends to clog the pump unit of the hydro-mulcher when the unit is shut off, preventing the pump from operating when the unit is restarted. Other mulching materials, such as rice hulls or cotton lint, cause similar problems and, like sawdust, do not provide good erosion protection. Straw mulch is not compatible with the tank-mixing aspect of the hydro-mulcher. If a hydro-mulcher is to be used as a one-step operation, then the fiber-mulch material should be procured. Humectant, which provides moisture to the developing seedlings, is necessary for establishing vegetation during the dry season. The humectant is hygroscopic: it removes moisture from the air and makes it available to the plants. If vegetative establishment is performed at the start of the rainy season, humectant can be eliminated. Lime can be obtained locally in Honduras. Either hydrated lime or ground limestone (agricultural limestone) can be distributed through the hydro-mulcher; however, the lime should be applied in a separate operation from seeding. There is no fertilizer industry in Honduras. Fertilizer to be tank mixed in the hydro-mulcher should be water soluble.

24. The soil samples collected by Mr. Pecoff were analyzed by a consulting laboratory. WES investigators find several points of contention with

the soil test reports and subsequent fertilizer recommendations. First, they believe that the conversion of the analytical results from parts per million (ppm) to pounds per acre is in error. The standard agricultural rule of thumb is an acre of soil 6 in. deep weighs 2 million pounds. This means that a soil analysis of 2 ppm would be equal to 4 lb/acre. The lab performing the soil analysis for Mr. Pecoff used a conversion factor of 8, instead of the standard conversion factor of 2. The fertilizer recommendations do not appear to be low as a result of this error; on the contrary, they seem to be excessively high. WES's fertilizer recommendations (Appendix D) are included for each site and are quite different from those used in Mr. Pecoff's report. It should be noted that in a subsequent recommendation, Mr. Pecoff reduced the amount of fertilizer recommended from the testing lab's 1,000 lb/acre to 300 lb/acre of 12-12-12.

25. WES's second contention is with the recommended fertilizer sources. Locally available organic fertilizers are not suitable substitutes for chemical fertilizers in the vegetation establishment phase under Honduran conditions. Since all chemical fertilizers will have to be imported, minimizing the quantity of fertilizer required is essential. Fertilizer is sold based on the percentage of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) that it contains. The higher the percentages, referred to as analysis, the more concentrated the fertilizer source. The fertilizers recommended in Mr. Pecoff's report are low analysis fertilizers, 12-12-12 and 0-8-6. In the former, 36 lb of plant nutrients is contained in every 100 lb of fertilizer. In the latter, only 14 lb of plant nutrients is contained in every 100 lb of fertilizer. In the latter instance, 86 lb of filler that provides no plant nutrients must be transported. WES personnel recommend that standard granular fertilizers having the following formulations be used: ammonium nitrate (34-0-0) or urea (45-0-0) to supply nitrogen; triple super phosphate (0-46-0) to supply phosphate; and muriate of potash (0-0-60) to supply potash. Considerable savings in shipping costs could be achieved through the use of the concentrated fertilizer formulations. Additionally, the more concentrated forms of fertilizer are usually less expensive per unit cost of plant nutrient. As mentioned in paragraph 23, water soluble fertilizers are best suited for use with the hydro-mulcher. Water soluble fertilizers tend to be more expensive than less soluble, granular formulations. The main advantage of water soluble fertilizers is that they will completely dissolve and thus be equally distributed

throughout the mix. Granular fertilizers may not completely dissolve and may not be as well distributed in the tank and on the ground.

26. Based on WES's review of the soil analysis data, there is no need to apply sulfur, iron, or manganese to any of the soils with a pH < 7 . These compounds are soil acidifiers, which should be used when the soil pH > 7.5 . If hydrated lime is used, there is a possibility that iron and manganese, as well as some other nutrients, could be temporarily unavailable for plant uptake. Hydrated lime reacts very rapidly with the soils to neutralize soil acidity. As the pH of the soil increases towards 7.0, iron precipitates out of the soil solution, becoming less available for plant uptake. The use of hydrated lime may result in the formation of localized pockets having a very high pH. Within these high pH pockets, iron, manganese, boron, copper, zinc, and phosphorus may precipitate out of the solution, becoming unavailable for plant uptake. WES personnel recommend that ground limestone be used instead of hydrated lime. Ground limestone neutralizes soil acidity more slowly and requires higher application rates per acre than hydrated lime, but the buffering effect is longer lasting and there are no problems of nutrient nonavailability.

27. In summary, WES investigators find nothing wrong with the species recommended by Mr. Pecoff for dust and erosion control in Honduras. His methods for establishing vegetation are sound. WES personnel believe that the recommendations for fertilizer rates are inaccurate and the recommended fertilizer formulations are inefficient or unnecessary. The methods and materials outlined and recommended by Mr. Pecoff provide the information necessary to be reasonably assured of successfully establishing a diversified ecosystem during the dry season to provide adequate vegetative cover for control of erosion during the rainy season.

PART III: FUERTES CAMINOS ROAD PROJECT

Description of Construction Site

28. The Fuertes Caminos project involves the construction of a two-lane military standard road between the towns of Yoro and Jocon. It is being constructed through very steep and rugged terrain by a number of engineer units, both Active and Reserve. The project is being constructed in phases, each phase representing a new construction season. Army engineer units are assigned a section of the road to construct during each phase. Slopes in the construction area average 30 to 40 percent and can exceed 100 percent, making water diversion and erosion control significant aspects of the construction project. Much of the native vegetation was either removed or covered during cut and fill operations; therefore, many embankments were left without vegetative cover.

Problems Identified

29. WES observations focused on the destructive effects of the unchecked surface water runoff. At numerous locations along sections of the road constructed during previous construction seasons, the road was undercut by water on the uphill side, or the embankment on the downhill side failed causing damage to the roadway surface. Since no water diversion or water control structures were observed in sections of the road presently under construction, it can be assumed that they too will suffer damage from surface water runoff once the rainy season begins. Many of the embankments left when cuts were made are too steep for effective vegetation establishment.

30. It also appeared that the amount of rainfall runoff was underestimated when culverts were designed. Review of the drainage basin estimates may expose the problem area; however, soil type and the density of vegetative cover can significantly influence water retention and runoff (infiltration capacity). If drainage estimates were accurate, then a closer look at the soil data and vegetative cover is in order.

Potential Solutions to Problem

31. The need for water diversion structures is clearly evident from WES observations of the problems. These structures include diversion and interception ditching, terracing or stepping embankments, checkdams, and emplacement of drainage tiles. Some embankments will require the protection of riprap or retaining walls. The purpose of water diversion structures is to reduce the energy of the runoff water. Creating turbulence (checkdams), causing the water to run perpendicular to the slope instead of parallel to it (ditches and tile drainage), or reducing the slope (terraces and steppes) will decrease the energy of the water and its erosive potential. Selection of the method or structure to be used will be site specific. Diversion ditching will be the most widely used method, because it complements the other methods. Riprap or retaining walls should be considered for use on near-vertical cut embankments, with a diversion ditch placed above the embankment. There are also fill embankments that require some type of retaining structure to prevent erosion from drainage of the road surface.

32. A number of sites during previous construction seasons could have benefited from the inclusion of checkdams. Culverts at several locations suffered from headwall erosion. Checkdams will reduce the velocity of water entering the culvert area, reduce the amount of debris entering the culvert, and reduce the flow of water into the ponding area. Attention should also be given to the ponding area. Failure of the culvert may have been due to a failure of the surrounding soil to prevent water infiltration. Properly designing and constructing the ponding area may reduce this problem.

33. Tile drainage is a method of reducing erosion by removing excess water from an area by providing a conduit in which it can flow. Tiles constructed of concrete, clay, or other material are placed in ditches across the area to be drained. Water enters the tiles and is directed to an outlet. There are a number of benefits from the use of tile drainage, e.g., removal of standing water, conservation of topsoil, and increasing the rooting zone of plants. Tile drainage, which does not require land formation, would be best suited for use on the long, wide fill embankments where runoff erosion is most severe and on embankments where the potential for subbase shearing is great. A more detailed discussion of tile drainage systems and design can be found in Appendix A.

34. Terraces and steppes are very effective in reducing soil erosion; however, they are costly to construct. Terraces are effective on slopes up to 14 percent, but steppes must be constructed when slopes exceed 14 percent. Both terraces and steppes require good sod cover to protect them from damage and to reduce the flow of water. Diversion ditches used in conjunction with terraces or steppes further direct water to culverts that can discharge the water at the bottom of the slope.

35. The establishment of vegetative cover is essential to controlling erosion, reducing water runoff, and preventing damage to the road. Precautions should be taken to avoid disturbing the native plant cover more than necessary during construction. Consideration for the preservation, establishment, and maintenance of vegetation should be made during the design process. When disruption of natural vegetative cover is unavoidable, reestablishment is essential. Seedbeds must be prepared properly. Embankments should be shaped to provide a suitable growing environment. Areas to be revegetated should not be compacted too greatly. The surface to a 3-ft soil depth should be lightly compacted and disked to a depth of 6 to 12 in. just prior to seeding if possible. Soil samples should be analyzed to determine the lime and fertilizer additions required to promote seedling establishment and plant growth. Lime should be applied to correct for soil acidity. If seeding is to be performed using a hydro-mulcher, then liming must be performed independently of seeding to prevent damage to the seeds. It is preferable that liming be performed 2 to 6 months prior to seeding. This will allow the lime to react with the soil to neutralize the acidity. Once the rough construction (all cut, fill, shaping, or land-forming operations) of an area to be seeded has been completed, lime can be applied up to the time of seeding; however, plant establishment will be enhanced by earlier application. Fertilization is another key to successful establishment. If granular fertilizers are to be used, they should be applied to the soil just prior to seeding and incorporated (disked) into the soil for maximum effectiveness. If seed is to be sown with a hydro-mulcher, the fertilizer can be tank mixed and applied with the seed.

36. A mulch covering is necessary for establishing seed on moderate to steep slopes. The mulch serves as a protective coating for the exposed soil and resists erosion while providing an improved microenvironment for seed germination and establishment. The use of a mulch and a humectant material is critical if reasonably successful establishment is to be achieved during the

dry season. Hay or straw properly crimped into the soil will serve this purpose on sites when hydro-mulch materials are not used. Mulches having long, interlocking fibers should be selected because they offer more resistance to erosion.

37. The selection of plant species depends on slope, soil type, elevation, ecological considerations, and land use plan (including forestry, grazing, or wildlife use). The plant species sown may include grasses, legumes, forbs, and trees. WES personnel recommend that a mixture of species be sown to provide the best chance for successful establishment and erosion control. Seeding rates should be adequate, but not excessive, since excessive rates promote competition for light, moisture, and nutrients that may be detrimental to the establishment and longevity of the stand. The following formula provides a rule of thumb for determining the seeding rate to use for a single species in a mixture:

Seeding Rate (Broadcast)/Total Number of Species in Mixture - 1

Plant species suitable for use in revegetation along the Fuertes Caminos Road are described in Appendix B and identified in Table B1.

Soil Fertility Status

38. Four soil samples were collected along various sections of the road project, three from the AT 88 section and one from the AT 87 section. As expected, all the soils were moderately acidic, ranging in pH from 5.3 to 5.8. Available phosphorus was very low for all the soils, but potassium was high (above 120 ppm). Micronutrient availability was generally low, but considered adequate for turf production. Fertilizer recommendations are 1 to 1.5 tons of lime, 120 lb of nitrogen (split 80 lb at seeding and 40 lb 4 weeks later), to 120 lb of phosphate, and 10 lb of sulfur per acre. Complete soil test reports are included as Appendix D.

Recommended Courses of Action

39. The following actions are recommended to reduce erosion on the Fuertes Caminos Road project:

a. Develop a revegetation plan to provide guidance on the types of vegetation suitable for use under a variety of conditions.

b. Develop construction guidance specifying when terraces or steppes and riprap or retaining walls will be constructed, where diversion ditches and checkdams will be placed, and under what conditions tile drainage should be considered.

c. Minimize the disturbance of native vegetation during construction.

d. Collect soil samples from areas to be revegetated. Have soil samples analyzed for lime and fertilizer requirements.

e. Apply recommended rates of lime and fertilizer prior to, or concurrent with, seeding.

f. Use a mulch on moderately to steeply sloping areas to protect the soil from erosion during seed germination and establishment.

g. Consider establishing vegetation during the dry season on areas susceptible to severe erosion.

PART IV: JTF BRAVO/PALMEROLA AIRBASE

Description of Construction Site

40. JTF Bravo/Palmerola Airbase is located on a plateau near Comayagua. The ecology of the area is similar to a chaparral. Most of the major construction in the area has been completed. During construction the native vegetation was removed and not replaced. The soil surface is littered with many rocks, most of which weigh less than 150 lb. JTF Bravo is home to nearly 3,000 US service men and women who are involved with joint task force operations. The airbase is also the home of the Honduran aviation training center.

Problem Identified

41. Dust is the major problem identified at JTF Bravo/Palmerola Airbase. Wind erosion is the result of frequent winds in the area and aircraft activity. Dust generated by traffic on the roads surrounding the airfield is a significant contributor to the overall problem. The dust permeates living quarters and offices and substantially increases maintenance costs for aircraft, vehicles, and other equipment. The dust problem is severe enough to be a health and morale consideration.

Potential Solutions to Problem

42. Immediate establishment of vegetative cover is essential. The dust problem will be substantially reduced once vegetation is established. Grass will provide the best ground cover. The grass best suited for use under conditions found in the cantonment area is bermudagrass (*Cynodon dactylon*), which can be established from seed (common) or sprigging (improved hybrids). Common bermudagrass will give satisfactory results and is also the least expensive to establish. It will require occasional watering and periodic fertilization for best performance. Bermudagrass forms a thick, dense sod and spreads to adjacent bare areas rapidly. The improved hybrid varieties are more resistant to traffic than the common variety. However, bermudagrass is not very shade tolerant, and WES personnel recommend the establishment of tree windbreaks.

When established (3 to 5 years), these will provide shade. Because of the cool evening temperatures at Palmerola, it is likely that the cool-season grass, creeping red fescue (*Festuca rubra*), will perform well in shady areas where supplemental water can be applied. Presently, there are very few shady areas at JTF Bravo/Palmerola. It is also likely that tall fescue (*Festuca arundinacea* Schreb.) or Kentucky bluegrass (*Poa pratensis*) could be established in the cantonment area where supplemental water can be applied; however, bermudagrass remains WES's primary choice.

43. WES personnel recommend the use of Star grass (*Cynodon alemfuensis*) for areas near the airfield. Star grass is more drought tolerant than bermudagrass and performs well under conditions of low fertility. It grows taller than bermudagrass and is suitable for cutting for hay. Star grass must be vegetatively propagated; it cannot be established from seed. The simplest way to establish Star grass is to cut an existing Star grass field, bale the green grass, transport the bales to the location of the field to be established, spread the cuttings over the new field, and crimp the cuttings into the soil. The cutting, baling, transporting, spreading, and crimping of the grass should be accomplished in the same day. If the entire operation cannot be accomplished in 1 day, the grass should be cut in the late afternoon and baled in the evening, with transporting, spreading, and crimping done early the following day. The cut grass should not be allowed to dry, or it will not survive. Water should be applied to the baled grass to reduce moisture loss. The grass cuttings will root, and within 4 to 6 weeks, the new field will be established. Star grass should be established during the wet season after the ground has been moistened by several rains.

44. A number of areas surrounding the airfield are covered with dead plant material. These areas should be cleared off to allow new vegetation to emerge. WES personnel recommend that controlled burning be performed on these areas. Burning will get rid of the dead material that is inhibiting new plant growth and, at the same time, release nutrients necessary to support new plant growth. Cutting the dead material out will not help promote new growth unless the dead material is removed. Burning is the simplest and most practical solution.

45. WES investigators observed large quantities of loose rock on the soil surface at several locations around the airfield. These rocks are a detriment to successful vegetation establishment and pose serious problems for

vegetation management. WES personnel recommend that they be removed before establishing vegetation. These loose rocks, once collected, could be stockpiled for later crushing and use in construction projects. Equipment is commercially available to remove loose rock from soil and collect it for field removal. WES personnel observed stockpiles of soil left during construction of the airfield. These should be leveled prior to vegetative establishment for ease of vegetation maintenance and to prevent unnecessary soil erosion.

46. Once the soil surface is leveled and rocks removed, the seedbed can be prepared. The results of the soil analyses obtained from samples collected by WES investigators indicate that liming is generally not required for successful vegetation establishment. There are a few areas where liming would be beneficial, but additional soil sampling and analysis are necessary to determine the locations and sizes of these areas. Lime could be applied as a topdressing to those areas requiring it after vegetation has been established. Fertilizer should be added and worked into the soil prior to planting. In the cantonment area, where the soil has been compacted by pedestrian traffic, the use of a rototiller will be necessary to prepare the seedbed. Because Star grass must be vegetatively propagated, dry, granular fertilizer is the best type of fertilizer formulation to use in areas adjacent to the airfield. Bermudagrass seed could be applied through a hydro-mulching machine. If seeded by a hydro-mulcher, a water soluble fertilizer can be tank-mixed with the seed. Bermudagrass can be established during the dry season; however, it will require supplemental watering to assure successful establishment.

47. A number of other grasses and legumes could be used at Palmerola. WES philosophy is to recommend species that can be expected to succeed with reasonable confidence, will require the least amount of technical expertise to establish, and are long-lived, aggressive sod-formers. The development of a diversified plant ecosystem is not desirable at the Palmerola airbase. WES personnel do not feel that a seed mixture containing shrubs is compatible with airfield use and safety. Some types of shrubs would increase fire risk during the dry season and would make controlling a fire more difficult. A solid stand of grass is the easiest type of vegetation to maintain over a long period of time.

48. The need for windbreaks at JTF Bravo/Palmerola is clearly evident. Windbreaks should be planned so that they do not interfere with flight operations and base security. Properly designed windbreaks will reduce the

distribution of dust throughout the cantonment area and will reduce the amount of dust blowing across the runway and aircraft maintenance areas. Tree and shrub species suitable for use in windbreaks at Palmerola include *Madina boreua*, a shrub having a terminal height of 5 m; eucalyptus (*Eucalyptus camaldulensis*), a very fast-growing species (2 to 5 m/year); and Arizona cypress (*Cuppressus* spp.). Windbreak planning is discussed in Appendix C.

Soil Fertility Status

49. Five soil samples were collected at JTF Bravo/Palmerola, all from areas adjacent to the airfield. These soils were found to be very high in potassium. The soil pH ranged from 6.6 to 8.4, ideal for plant growth. The soils were found to be variable in phosphorous content, ranging from very low to high. Micronutrient availability was high, but not excessive. Recommended rates of fertilization are 80 to 120 lb of phosphate and 120 lb/acre of nitrogen (split 80 lb at time of seeding and 40 lb 4 weeks later). No lime is required. Complete soil analysis results can be found in Appendix D.

Recommended Courses of Action

50. The following actions are recommended to reduce the dust problem at JTF Bravo/Palmerola Airbase:

a. Establish grass in the cantonment area. WES personnel recommend that common bermudagrass be sown using a hydro-mulch machine following seedbed preparation.

b. Establish grass in the areas adjacent to the airfield. WES personnel recommend Star grass in these areas.

c. Use selective burning to remove undecayed dead plant residue, thereby encouraging new growth.

d. Remove loose rocks and level soil mounds prior to establishing vegetation.

e. Fertilize in accordance with recommendations based on soil analysis results.

f. Prepare seedbeds for both the cantonment area and the areas adjacent to the airfield prior to sowing.

g. If dry season establishment of bermudagrass in the cantonment area is desired, assure that supplemental water will be available and will be applied.

h. Develop a windbreak design compatible with current and future base use and security requirements.

PART V: SAN LORENZO AIRFIELD

Description of Construction Site

51. The airfield at San Lorenzo is located in the southwest corner of Honduras, in the coastal plain referred to as the Pacific Lowlands. The region is very arid, and little vegetation was observed on the site. In areas adjacent to the site, scrub brush and forbs were growing. The entire airfield site is essentially level, except for some soil mounds left following construction of the parking apron.

Problem Identified

52. The primary challenge to establishing a vegetative cover at San Lorenzo is the arid climate. The soil is moderately acidic and would require pH adjustment prior to vegetative establishment. Vegetation establishment is feasible only during the rainy season at this site. Supplemental water for irrigation is unavailable.

Potential Solutions to Problem

53. Either bermudagrass or Star grass is suitable for use in revegetating the site. Other potential grass species for use are Lehmann lovegrass (*Eragrostis lehmanniana*), weeping lovegrass (*Eragrostis curvula*), buffelgrass (*Cenchrus ciliaris*), and Alkali sacaton (*Sporobolus airoides*). Three leguminous species that might be established at San Lorenzo are white sweetclover (*Melitotus alba*), yellow sweetclover (*Melitotus officinalis*), and sainfoin (*Onobrychis viciaefolia*). Establishing Star grass at this site may be more difficult than at other sites because of the less predictable rainfall. Common bermudagrass, as well as the other grass or forb species, could be seeded with a hydro-mulcher if an acceptable water source could be located. If seed is sown with a hydro-mulcher, WES personnel recommend that a humectant be included in the mix to increase the moisture available to the seed for germination. Direct seeding into a prepared seedbed could also be performed, but the likelihood of successful vegetation establishment would be much lower than if hydro-mulch seeded.

54. Eucalyptus (*E. camaldulensis*) and Caribbean pine (*Pinus caribaea*) trees would be useful in developing a windbreak for the airfield. The trees could also be used as part of a camouflage plan for the runway. Not only would the trees reduce the dust movement around the airfield, but they could also reduce the effects of cross winds. The best way to establish the trees is to plant 1-year-old seedlings and water them at the time of planting. A more detailed discussion of windbreaks can be found in Appendix C.

Soil Fertility Status

55. Four soil samples were collected at San Lorenzo. One of the samples was inadvertently collected in an area of the airfield that had been lime stabilized. The soil pH of the three remaining samples indicated that lime application was not necessary for vegetation establishment. Available phosphate was low, and potassium ranged from high to very high. As expected, the organic matter content of the soil was low. Micronutrient availability was low, but adequate for turf production. The sodium content of the soil was high, but soluble salts (as determined by electroconductivity) were low. The recommended rates of fertilizer are 120 lb of phosphate, 10 lb of sulfur, and 120 lb of nitrogen (split 80 lb at planting and 40 lb applied 4 weeks later) per acre. Complete soil analysis results are provided in Appendix D.

Recommended Courses of Action

56. The following actions are recommended to reduce the dust problem at the San Lorenzo airfield:

a. Establish grass in areas adjacent to the runway and parking areas. Bermudagrass, Star grass, or one of the lovegrasses are the species most likely to succeed.

b. Fertilize the site in accordance with fertilizer recommendations, and prepare a good seedbed prior to sowing seed or sprigging plants.

c. The use of hydro-mulching to establish vegetation from seed is highly recommended because of the need to conserve and retard the loss of water. A humectant compound in the hydro-mulch mixture is also recommended.

d. Establish a windbreak to reduce winds blowing across the runway.

e. Because of the harsh environment at San Lorenzo, WES personnel recommend that grass test plots be established to test several species for adaptability to the area before any one species is selected.

PART VI: JAMASTRAN AIRFIELD

Description of Construction Site

57. The airfield at Jamastran is located in south-central Honduras, about 16.5 km from the Nicaraguan border. It is situated in a valley between two mountain ranges. The airfield presently has a good vegetative cover on it, although desirability of the species may be questionable. When viewed by the WES investigators, predominant vegetation on the areas adjacent to the runway was medium-sized shrubs. Some grass was observed in tufts around the shrubs, but grass growth could not be considered good. The area was being grazed by horses at the time WES personnel viewed it, and cattle were grazing in surrounding pastures. Periodic grazing by cattle and horses can be assumed to continue to occur in the future.

Problem Identified

58. No major problems were observed at Jamastran in terms of a lack of vegetative cover. The problem is improvement of the existing vegetative cover. The dust problem at Jamastran could be further reduced if a sod-forming grass such as bermudagrass or a mounding bunchgrass like the lovegrasses was established. Some bermudagrass is present at Jamastran now.

Potential Solutions to Problem

59. Fertilization of the areas adjacent to the airfield would stimulate grass growth and promote the spread of the bermudagrass presently there. Fertilization encourages competition between grass and weed species so that the grasses will choke out the weeds. Sowing bermudagrass or lovegrass seeds by hydro-mulching is a viable means of introducing different grass species without removing the shrub cover present. Broadcast seeding on the surface may also be performed satisfactorily, but its success depends more on timely rainfall than does the hydro-mulch method. Bermudagrass makes excellent pasture when properly fertilized and maintained. This could be a detriment at this airfield because of the number of animals in the area. The potential for over-grazing and subsequent destruction of the grass cover should be

considered. Frequency of airfield use should also be considered. Large numbers of animals grazing adjacent to the runway could present significant aircraft safety hazards and interrupt flight operations. The lovegrasses are less palatable to livestock, reducing the potential for having animals on the airfield and interfering with flight operations. Alternatively, bermudagrass pastures could be established adjacent to the airfield to provide good grazing land around, but not on, the airfield. Lovegrasses or another unpalatable grass could be used on the areas immediately adjacent to the airfield. The alternative strategy assumes that the lovegrasses are more palatable than the native grasses presently on the site.

60. Another option is to remove the shrubs onsite and prepare a good seedbed for establishing a solid stand of grass. WES personnel recommend this option only if the user decides that the shrubs pose a safety hazard or security threat. If neither of these conditions exists, then the methods outlined in the previous paragraph should be used. If it is decided that the shrubs must be removed, they should be killed chemically. A registered brush killer should be used. Once dead, the brush can be removed with a blade or burned (unless burning is restricted by the directions printed on the chemical label).

61. Windbreaks should be established to reduce the dust signature of aircraft operations. The problem of dust blowing onto the airfield from adjacent areas does not appear to be significant at Jamastran. WES personnel recommend that *Acacia manqium* and *Casuarina equisetifolia* be used to establish windbreaks adjacent to the airfield. Details of windbreak establishment are discussed in Appendix C.

Soil Fertility Status

62. Three soil samples were collected at Jamastran. The soil reaction was found to be neutral or above neutral; no lime will be required. Available phosphorus ranged from medium to very high, and potassium was very high. Excessive sodium was found to be present in the soil and may be of concern when selecting plant species to be sown at Jamastran. The organic matter content of the soil is high, which may act to buffer the impact of excessive sodium. Nitrogen is the only fertilizer required, and it should be applied at

the rate of 120 lb/acre (split 80 lb at planting and 40 lb applied 4 weeks later). Complete soil analysis reports are provided as Appendix D.

Recommended Courses of Action

63. The following actions are recommended at the Jamastran airfield to reduce dust:

a. Fertilize in accordance with fertilizer recommendations.

b. Seed bermudagrass or a lovegrass by hydro-mulching.

c. Establish windbreaks to reduce the dust signature of airfield operations.

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APPENDIX A: DRAINAGE SYSTEM CONSTRUCTION CONSIDERATIONS

1. Drainage and terracing are methods of controlling and canalizing the rainfall runoff from slopes, embankments, and depressions to prevent or reduce soil erosion. When soil becomes saturated or a storm event occurs with rainfall intensity greater than the soil percolation rate, water flows over the surface of the soil. This overland flow follows the path of least resistance and increases in velocity in relation to path length and percent slope. Unchecked, the energy developed by this water can become great and destructive. Failure to control runoff can result in a failure of roads, bridges, embankments, and other structures.

2. Drainage and terracing complement each other and are often used in conjunction with each other. Terraces or steppes reduce the velocity of the water as it descends a slope. Interception or diversion ditches canalize the flow of water to a central discharge point. Tile drainage provides an underground conduit for the removal of excess surface water and permits the water discharge point to be selected by design, rather than by fall line. It is recommended that a soils engineer be consulted when developing the design for a drainage or terrace system.

Drainage Benefits

3. Drainage of land has a number of positive effects on the conservation of the soil and on the plants grown on the drained land. In tropical regions, the benefits of drainage also include disease control. Drainage of areas where water remains stagnant denies insects of breeding grounds and aids in the prevention of diseases such as malaria. The primary benefit gained by a drainage system is soil conservation and erosion control. The interception of runoff water and its canalization prevent the water from gaining high velocities and eroding soils at random points. From an engineering standpoint, the control of runoff water is essential to the prevention of a construction project's being destroyed or damaged by soil erosion.

4. Plants also benefit from drainage. Studies have shown that plant root systems develop more fully in soils that have been drained than in undrained soils. Because plants in drained soils have a better developed root

system, they are better able to withstand the stresses of a prolonged drought than plants growing in undrained soils.

Types of Drainage Systems

5. The main types of drainage systems are surface and subsurface drainage. Surface drainage is the removal of excess surface water by developing a slope to direct the flow of water in a desired direction. Land forming and ditches are common methods of surface drainage. Surface drainage techniques are best employed on gently sloping or flat land. A good discussion of surface drainage construction is found in TM 5-330.* Subsurface drainage is the removal of excess ground water from the soil. Tile and pipe drains are often used as conduits for the collection and discharge of excess ground water. Open ditches are also used for subsurface drainage if they are of sufficient depth and properly located.

6. Surface drainage ditch systems are of three types: random, parallel, and cross slope. Random ditches are shallow ditches used in undulating land where only scattered wet areas require drainage. The parallel ditch system is adapted to flat land where the need for drainage is uniform across the area, while the cross slope ditch system is employed to drain wet sloping land.

7. The construction of the Fuertes Caminos Road involves numerous cut and fill operations through steeply sloped terrain. Both surface and subsurface drainage systems should be considered for use to divert and intercept runoff water, increase infiltration, and reduce soil erosion. In general, the use of drainage along the Fuertes Caminos Road project is not for the purpose of draining wet, soggy areas, but for the purpose of reducing soil water runoff and prevention of soil shearing due to the accumulation of excess ground water.

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* Headquarters, Departments of the Army and Air Force, 1968, "Planning and Design of Roads, Airbases, and Heliports in the Theater of Operations," TM 5-330, Washington, DC.

Drainage Design Considerations

8. The first factor to be determined when developing a drainage plan is the size of the drainage basin. Techniques for determining the size of the drainage basin are outlined in detail in TM 5-330. The volume of water to be handled by the drainage system can be calculated once the size of the drainage basin is known by using locally obtained rainfall intensity data (preferred) or the world isohyetal map (Figure A1).

9. Once the volume of water to be handled by the system has been calculated, the point of water discharge should be carefully considered. The location and adequacy of the drainage outlet should be determined early in the design process. The proper functioning of the entire drainage system is linked to the adequacy of the drainage outlet. In determining the adequacy of the drainage outlet, the following should be considered:

a. The capacity of the outlet should permit the design flow to be discharged at an elevation equal to or less than the hydraulic gradeline used for designing the project.

b. The capacity of the outlet must be such that the discharge from the project area will not have adverse impacts below the project area.

c. Flow conditions should not produce excessive scour or deposition of sediment at the outlet.

10. If the outlet is determined to be inadequate, a decision must be made to improve the outlet, to improve the other factor(s) resulting in the outlet being inadequate, or to construct water retaining or sedimentation ponds above the outlet. Under Honduran conditions, the predominant factor in determining the adequacy of the outlet is the impact of discharge water on stages downstream.

11. Another important factor in determining the potential volume of runoff water to be handled by the drainage system is the rate at which water infiltrates the soil. Infiltration rates for various soils and materials are listed in Table A1. The infiltration rate is significantly affected by the amount of vegetative cover present. For design purposes, the area to be denuded of vegetative cover should be considered unless provisions have been made for the preservation of vegetation or the revegetation of the area prior to the occurrence of significant storm events.

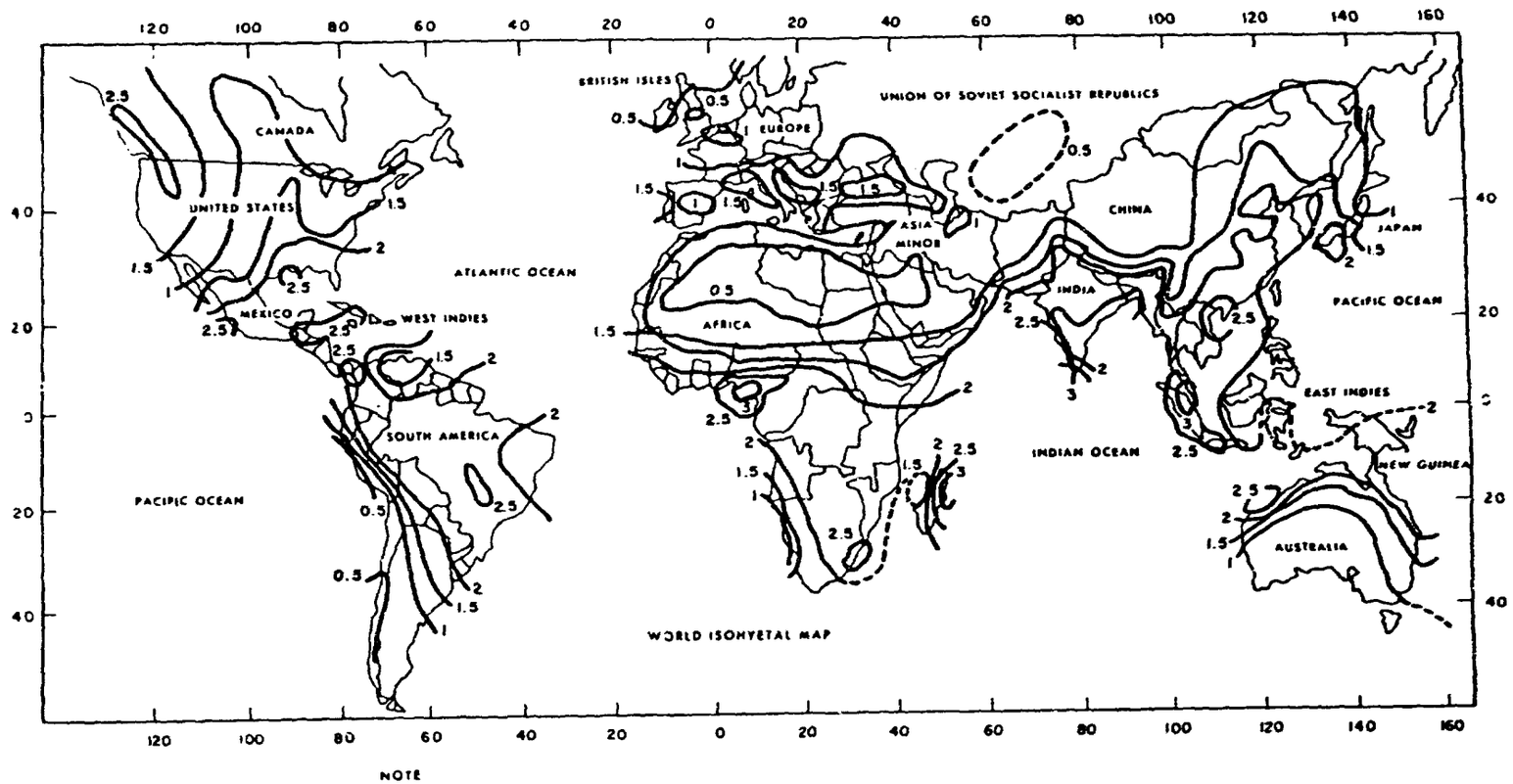

Figure A1. World isohyetal map (TM 5-330)

Table A1

Infiltration Rate, Inches per Hour

Major Divisions	Symbol	Dense Cover	Average Cover	Sparse Cover
		Coarse Grained		
Gravel and gravelly soils	GW	1.0 - 1.5	0.8 - 1.2	0.6 - 1.0
	GP	1.0 - 1.5	0.8 - 1.2	0.6 - 1.0
	GM d	0.6 - 0.8	0.4 - 0.6	0.2 - 0.4
	GM u	0.4 - 0.5	0.3 - 0.4	0.2 - 0.3
	GC	0.3 - 0.4	0.2 - 0.3	0.1 - 0.2
Sand and sandy soils	SW	1.0 - 1.5	0.8 - 1.2	0.6 - 1.0
	SP	1.0 - 1.5	0.8 - 1.2	0.6 - 1.0
	SM d	0.6 - 0.8	0.4 - 0.6	0.2 - 0.4
	SM u	0.4 - 0.5	0.3 - 0.4	0.2 - 0.3
	SC	0.3 - 0.4	0.2 - 0.3	0.1 - 0.2
		Fine Grained		
Silt and clays LL < 50	CL	0.1 - 0.2	0.1 - 0.2	0.02 - 0.1
	ML	0.6 - 0.8	0.4 - 0.6	0.2 - 0.4
	OL	0.6 - 0.8	0.4 - 0.6	0.2 - 0.4
Silt and clays LL > 50	CH	0.1 - 0.2	0.1 - 0.2	0.02 - 0.1
	MH	0.6 - 0.8	0.4 - 0.6	0.2 - 0.4
	OH	0.1 - 0.2	0.1 - 0.2	0.02 - 0.1
Highly organic soils	PT	0.6 - 0.8	0.4 - 0.6	0.2 - 0.4

Note: For pavements, use zero. A very high water table will reduce infiltration capacity, particularly in coarse-grained soils.

12. When ditches are to be used, soil and maintenance factors should be considered in designing side slopes. The side slopes of ditches vary with the type of soil material in which they are constructed. Recommended side slopes for main and lateral ditches are as follows:

Soil	Side Slope
Loam	2:1
Clay	1.5:1
Peat, muck, and sand	1:1

13. The method of ditch maintenance will also determine the steepness of the side slope to be constructed. Ditch side slopes recommended for various maintenance techniques are listed in Table A2.

14. Soil factors must be considered when the maximum permissible velocity of flow through the ditch is to be determined. Flow velocities increase as the percent fines or gravel in a soil increases (Table A3).

15. Land forming is generally associated with agricultural practices; however, it does have applications in construction design. Grading slopes to canalize excess surface water in a particular direction is an application of land forming. Consideration should be given to the impact of runoff water when embankments are graded. A small amount of additional fill may greatly affect the life of the project by reducing the soil erosion potential of the runoff water.

16. Subsurface drainage should be considered when:

a. There is a need to remove excess ground water.

b. Resources for periodic maintenance of ditches are not available.

17. Subsurface drainage may be difficult to construct on very steep slopes because of equipment and material requirements; however, subsurface drainage is feasible on steep slopes when used in conjunction with terraces or steppes. A discussion of subsurface drainage can be found in Chapter 6, paragraphs 6-35, of TM 5-330; however, a more in-depth discussion can be found in Chapter 14 of the Engineering Field Manual, Soil Conservation Service, US Department of Agriculture.* A brief discussion of subsurface drainage systems follows.

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* US Department of Agriculture, 1984, Engineering Field Manual, Soil Conservation Service, Washington, DC.

Table A2

Ditch Side Slopes Recommended for Maintenance

Type of Maintenance	Recommended Steepest Side Slopes	Remarks
Mowing	3:1	Flatter slopes desirable
Grazing	2:1 or flatter	For ditches greater than 4 ft deep
	1-1/2:1 or flatter	For ditches less than 4 ft deep
Dragline	1/2:1	Usually used on ditches with steep side slopes, greater than 4 ft deep
Blade equipment	3:1	Flatter slopes desirable
Turning plows	3:1	Flatter slopes desirable
Chemicals	Any	Use caution near crops
Burning	Any	

Table A3

Limiting Velocities of Design High Water for Various Soils and Materials

Soil Texture	Maximum Velocity ft/sec
Sand and sandy loam (noncolloidal)	2.5
Silt loam (also high lime clay)	3.0
Sandy clay loam	3.5
Clay loam	4.0
Stiff clay, fine gravel, graded loam to gravel	5.0
Graded silt to cobbles (colloidal)	5.5
Shale, hardpan, and coarse gravel	6.0

18. The need for and design of subsurface drainage systems are determined by the amount of excess water entering the soil, the permeability of the soil, and underlying subsoil materials. Fine-textured soils are less permeable than coarse-textured soils. Therefore, they drain more slowly and may cause clogging of the drainage system as the result of an accumulation of fine particles in the filter surrounding the system.

19. Interception drainage is the type of subsurface drainage most suitable for use along the Fuertes Caminos Road. Interception drains are installed at right angles to the flow of surface and ground water. It is important to understand ground-water movement when determining where to place interception drains (Figure A2). Locating and intercepting seepage points are important from an erosion-control standpoint.

20. Either ditches or subsurface drains can be used for subsurface drainage. The ditches are generally V-shaped with the tops and bottoms rounded out. The finished ditch conforms to a hyperbolic or parabolic section, depending on the width of the ditch. Spacing between ditches should be approximately 200 ft.

21. Drains are commonly manufactured from clay, concrete, bituminous fiber, asbestos cement, plastic, and metal. Specifications of the individual materials vary and there are often different grades among drains of the same material. Therefore, attention to the specifications of the drain is essential. Trench depth is also an important factor in determining the specifications of the tile to be used (Table A4).

22. Inflow rates into tile drains are influenced by the soil texture as shown in Table A5. The need for filters, envelopes, and minimum flow velocities are also affected by soil texture (Table A6). Filters are used to facilitate the inflow of water into the drain while preventing the fine soil particles from entering the drain. Filters can be of a variety of materials, e.g. topsoil, straw, sawdust, tar paper, and fiber glass. However, the best filter material is a mixture of sand and gravel. Envelopes provide a bed for the drain and assure that it is properly supported.

23. There are several types of surface inlets, but the type most suited for use along the Fuertes Caminos Road is the blind surface inlet (Figure A3). The blind surface inlet is constructed in layers, with each descending layer being more porous than the previous one. This type of outlet is susceptible

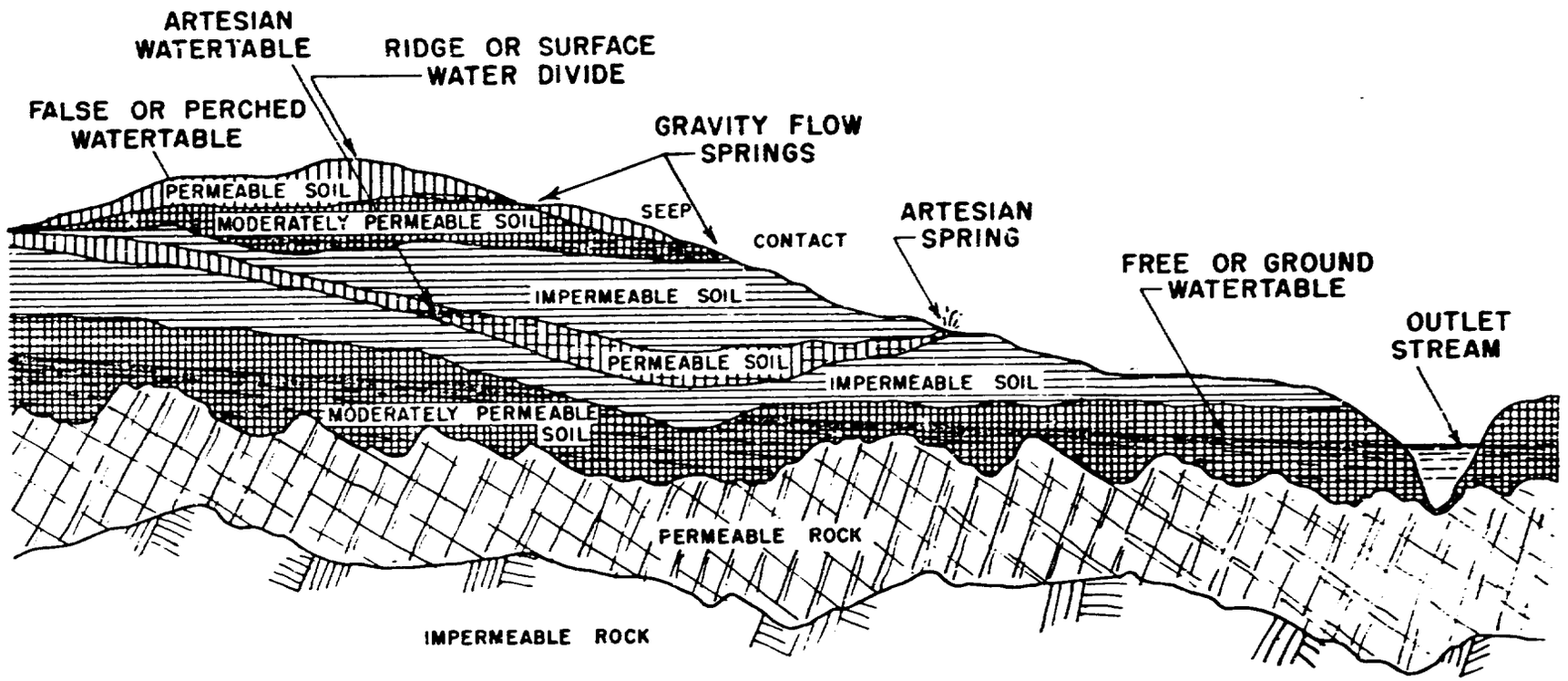


Figure A2. Ground-water movement

Table A4

Maximum Allowable Trench Depth for Drains with Varying Widths of Trench Based on Ordinary Bedding, Feet*

Tile Size in.	Strength lb/lin.ft	Width of Trench, in. 14	16	18	20	22	24	26	28	30
	800	Inf.**	13.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
4	1,100		Inf.	Inf.	12.5	12.5	12.5	12.5	12.5	12.5
	800		16.5	8.5	7.5	7.5	7.5	7.5	7.5	7.5
5	1,100		Inf.	Inf.	12.0	9.5	9.5	9.5	9.5	9.5
	800			8.5	6.5	6.5	6.5	6.5	6.5	6.5
6	1,100			Inf.	12.5	8.5	8.5	8.5	8.5	8.5
	800			9.0	7.0	6.0	5.5	5.5	5.5	5.5
8	1,100			Inf.	12.5	9.0	7.5	7.0	7.0	7.0
	800			9.0	7.0	6.0	5.5	5.0	5.0	5.0
10	1,100			Inf.	12.5	9.0	7.5	6.5	6.0	6.0
	800			9.5	7.5	6.0	5.5	5.0	4.5	4.5
12	1,100			Inf.	13.0	9.0	7.5	7.0	6.0	5.5
	870				8.5	7.0	6.5	6.0	5.0	5.0
15	1,100				13.0	9.5	8.0	7.0	6.5	6.0
	930						7.0	6.5	6.0	5.5
18	1,200						9.5	8.5	7.5	7.0

* Reference: Based on Marston's formula, where soil = 120 lb/ft^3.

** Inf. = infinity.

Table A5

Interception Tile Flow Rates

Soil Texture	Inflow Rate per 1,000 ft of Line in cfs*
Coarse sand and gravel	0.15 to 1.00
Sandy loam	0.07 to 0.25
Silt loam	0.04 to 0.10
Clay and clay loam	0.02 to 0.20

* Discharge of flowing springs or direct entry of surface flow through a surface inlet or filter must be added. Such flow should be measured or estimated. Required inflow rates for interceptor lines on sloping land should be increased by 10 percent for slopes 2 to 5 percent, by 20 percent for 5 to 12 percent, and 30 percent for slopes over 12 percent.

Table A6

Classification to Determine the Need for Drain Filters, Envelopes, and Minimum Flow Velocities

Unified Soil Classification	Soil Description	Filter Recommendation	Envelope Recommendation	Recommendations for Minimum Drain Velocity
SP (fine)	Poorly graded sands, gravelly sands		Not needed where sand and	
SM (fine)	Silty sands, poorly graded sand-silt mixtures		gravel filter is used but	
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Filter needed	may be needed with flexible drain and other type filters	None
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not needed where sand and gravel filter	
SC	Clayey sands, poorly graded sand-clay mixtures		is used but may be needed	With filter--none
GM	Silty gravels, poorly graded gravel sand silt mixtures	Subject to local onsite	with flexible drain and other	Without filter - 1.40 ft/sec
SM (coarse)	Silty sands, poorly graded sand-silt mixtures	determination	type filters	
GC	Clayey gravels, poorly graded gravel-sand-clay mixtures			
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		Optional	None--for soils with little or no fines
SP, GP (coarse) GW	Same as SP & GP above. Well-graded gravels, gravel-sand mixtures, little or no fines	None	May be needed with flexible drain	

(Continued)

Table A6 (Concluded)

Unified Soil Classification	Soil Description	Filter Recommendation	Envelope Recommendation	Recommendations for Minimum Drain Velocity
SW	Well-graded sands, gravelly sands, little or no fines			1.40 ft/sec for soils with appreciable fines
CH	Inorganic, fat clays			
OL	Organic silts and organic silt-clays of low plasticity			
OH	Organic clays of medium to high plasticity			
Pt	Peat			

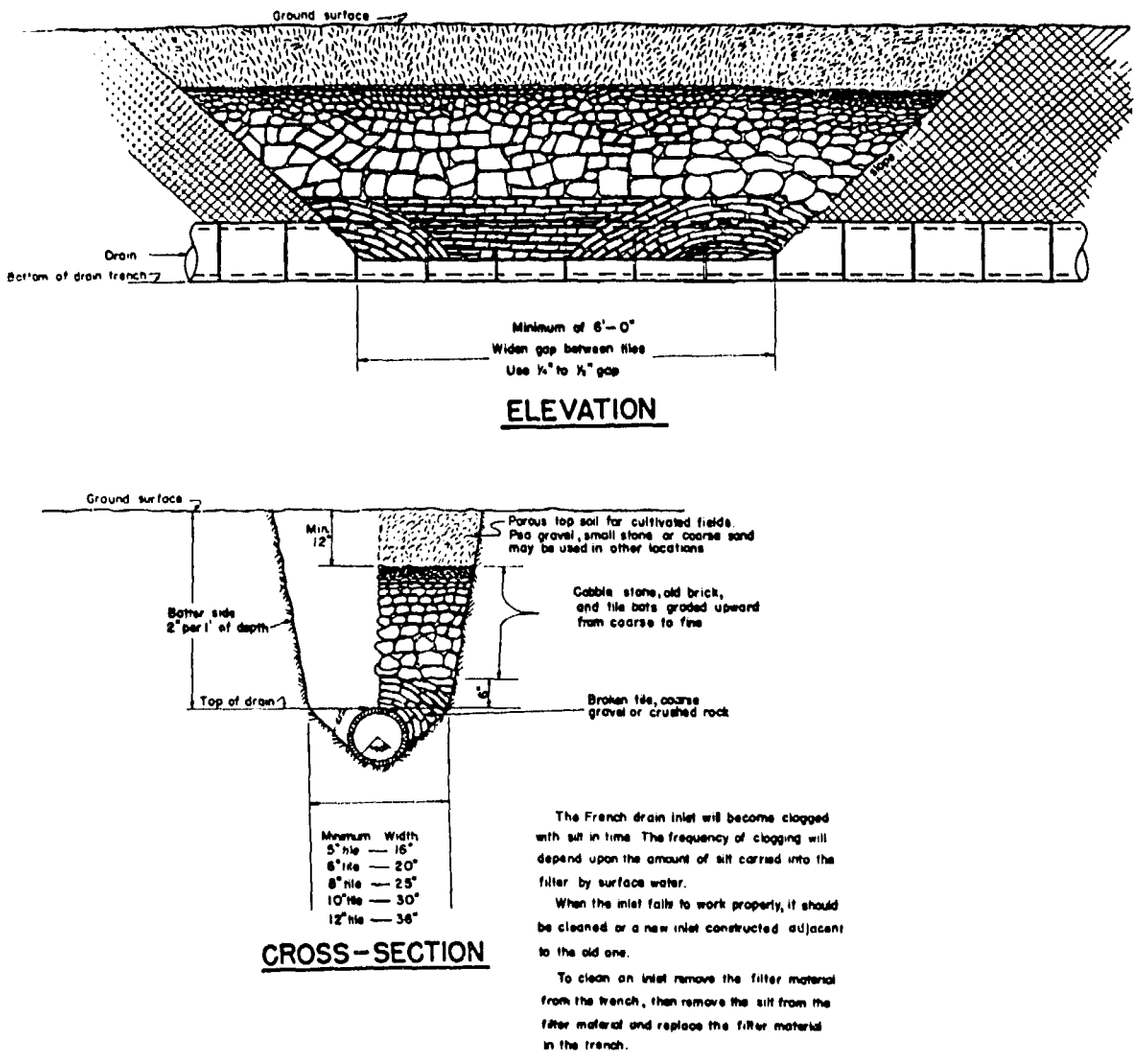
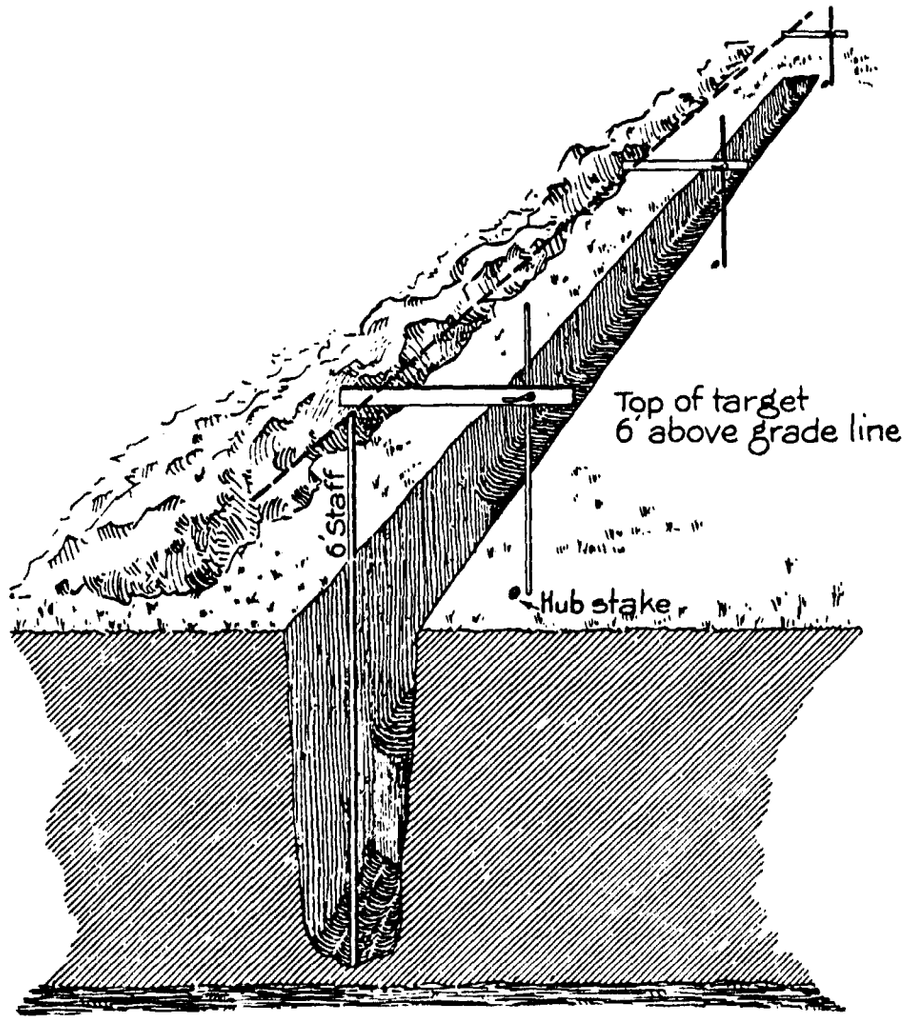


Figure A3. Blind surface inlet

to silting, but can be constructed with materials readily available in the theater of operations.

24. General tile emplacement techniques are illustrated in Figures A4, A5, and A6. A guide for determining the required size of concrete or clay drain tile is given as Figure A7.

METHOD OF USING TARGETS FOR LAYING TILE



CRADLING TILE IN UNSTABLE SOILS

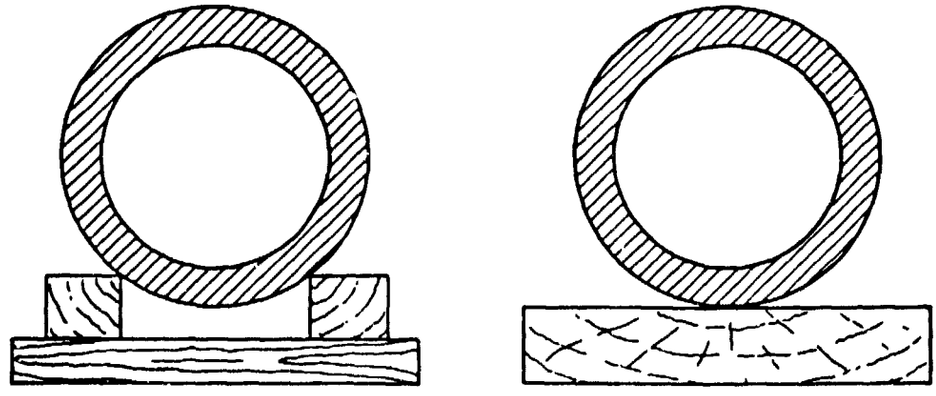
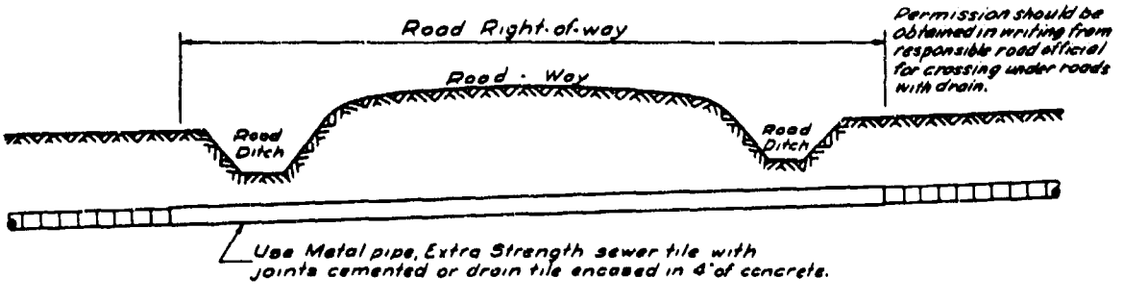
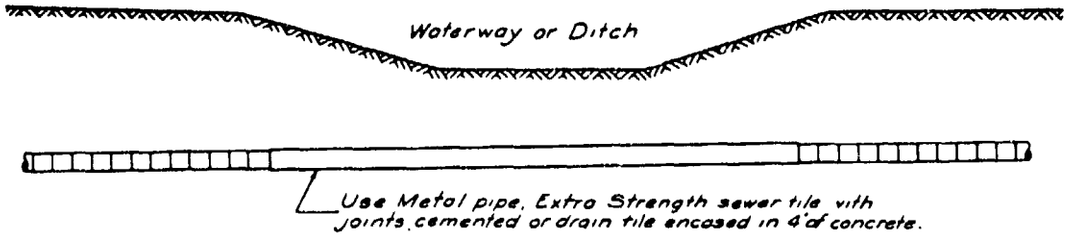


Figure A4. Installing tile

DRAIN CROSSING UNDER ROAD



DRAIN CROSSING UNDER WATERWAY OR DITCH



METHODS FOR HANDLING SHALLOW DEPTHS AT DRAIN OUTLET

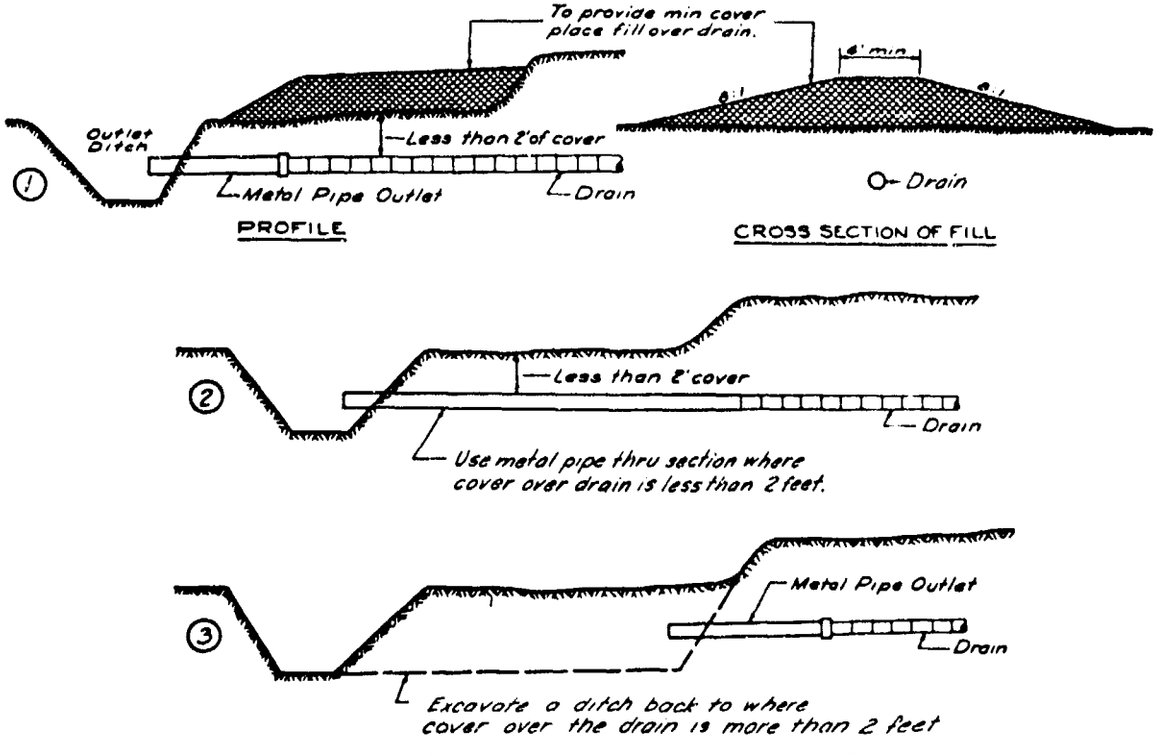


Figure A5. Drain crossings and outlets

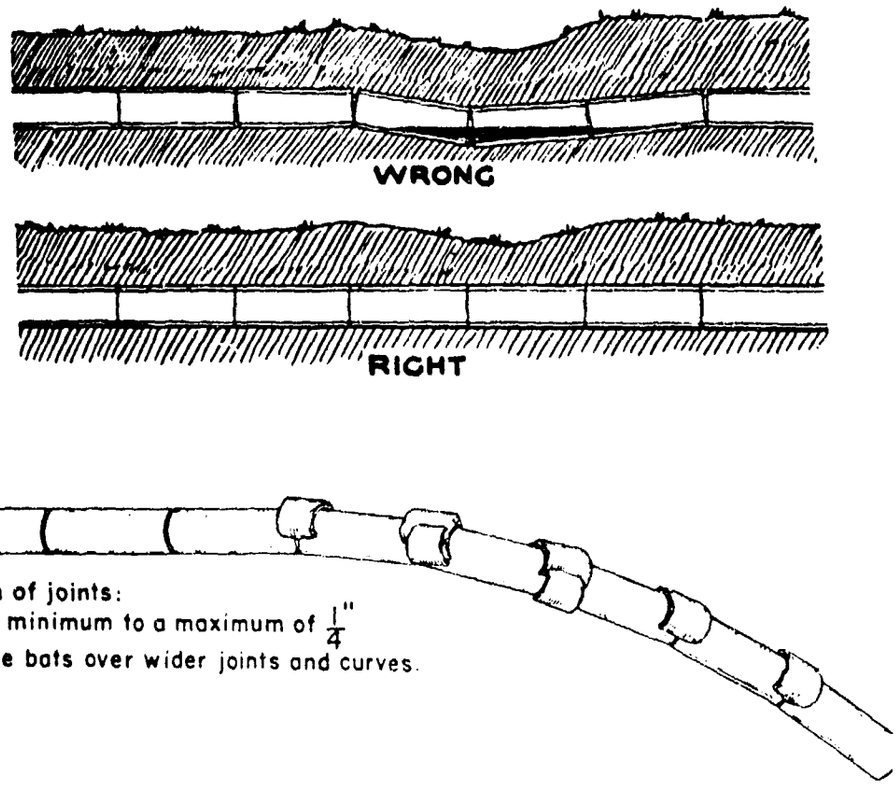


Figure A6. Laying tiles

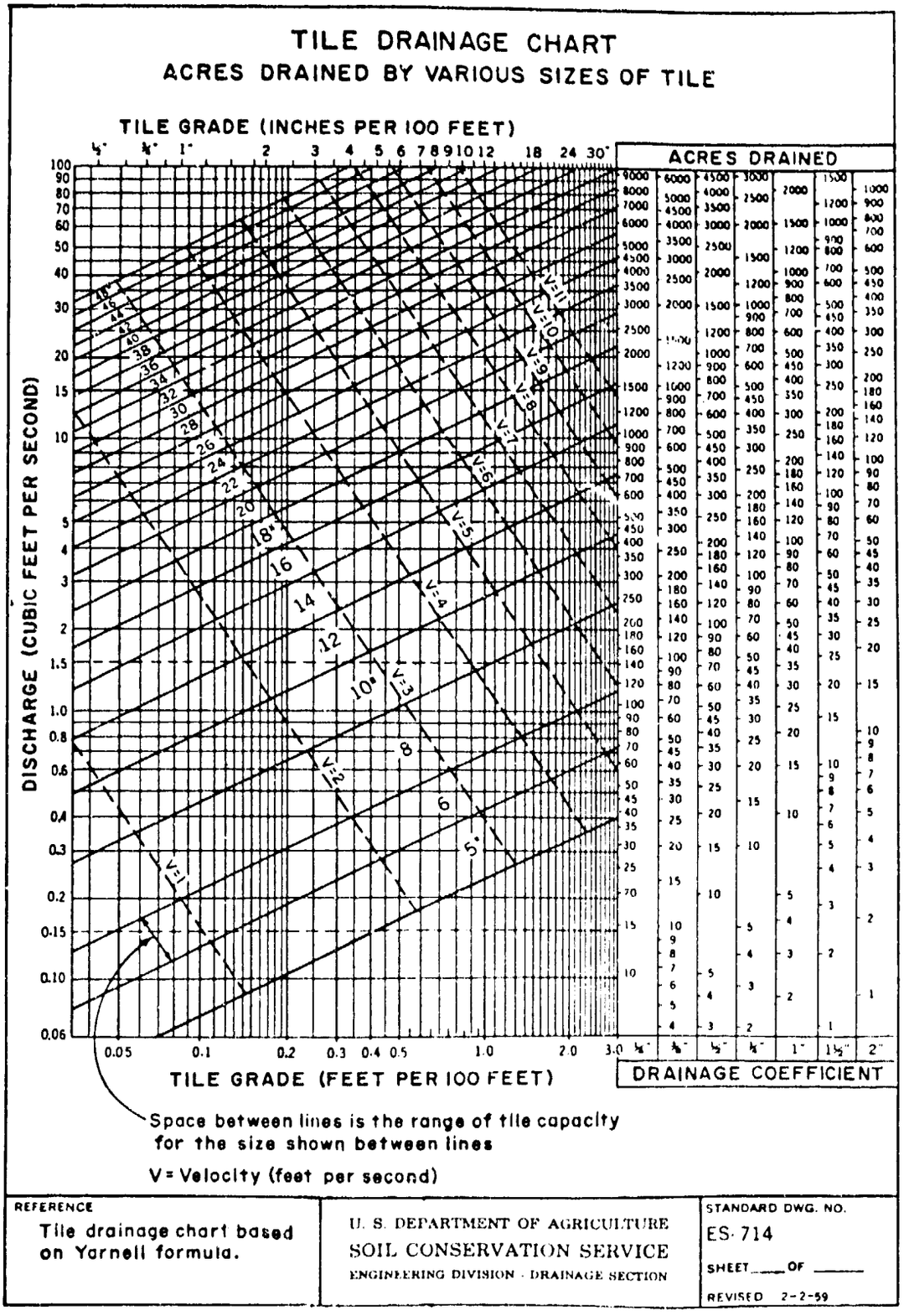


Figure A7. Chart for determining required size of clay or concrete draintile

APPENDIX B: AGRONOMIC CONSIDERATIONS AND PLANT SPECIES RECOMMENDED

Agronomic Considerations

1. Plant growth is influenced by environmental factors; each plant species has a range of tolerance for each environmental factor. Plant performance can be improved by adjusting environmental factors to the optimal range and correcting excesses or deficiencies that adversely affect the plant. Successful revegetation of disturbed areas will be enhanced if several agronomic factors are considered prior to sowing seed. Soil fertility is the agronomic and environmental factor most overlooked when vegetation is to be established. Yet, with the exception of soil moisture, soil fertility is the factor that will have the greatest influence on the success or failure of vegetation establishment. Soil fertility can be divided into three primary areas of concern: nutrient availability, soil reaction, and soil salinity. Nutrient availability refers to the soil's ability to supply the elements essential for plant function. There are 16 nutrients essential for plant function. Among these necessary nutrients are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Carbon, hydrogen, and oxygen are supplied by the atmosphere and do not limit plant function under normal conditions (under waterlogged conditions, oxygen may become deficient; see discussion under soil moisture). Nitrogen, phosphorus, and potassium are the nutrients found to be deficient in soils most frequently. Relatively large amounts of nitrogen, phosphorus, and potassium are required for plant growth and development. Plants growing on soils deficient in these nutrients are growing under stress and become more susceptible to other adverse environmental factors. The remaining seven elements are considered micronutrients; while no less essential, their role in plant function is limited. Micronutrient deficiencies are rare and are usually observed only in high-yielding crops.

2. Soil reaction, which refers to the acidity or alkalinity of the soil, is determined by measuring the concentration of free hydrogen ions present in the soil solution and is expressed as pH. Plants perform best when grown in soils having a pH of between 6.0 and 7.5; the optimal pH is around 6.5. The availability of several essential plant nutrients is reduced when the soil pH falls below 6.0, and nutrient deficiency symptoms may become

evident when the pH is less than 4.5 to 5.0 (Figure B1). Individual plant species have varied tolerances to soil reaction; some can survive in both moderately acid and moderately alkaline soils, whereas other plants will survive only in soils having a narrow pH range. The pH of the soils sampled in Honduras by US Army Engineer Waterways Experiment Station (WES) personnel ranged from moderately acidic to slightly alkaline. Ground limestone is used to correct acid soils. The quantity of lime required to neutralize a particular soil is dependent upon the surface area of the soil. Fine-textured soils have more surface area per unit of volume than coarse-textured soils. Because of the greater surface area of the fine-textured soil, the concentration of hydrogen ions can be greater. More lime is required to neutralize the acidity of a fine-textured soil than a coarse-textured soil having the same pH. Because of the influence of soil texture on the lime requirement, it is important to have a complete soil analysis performed on soil samples from the site to be revegetated, including the lime requirement. The application of lime should be considered part of the fertilizer application.

3. When the soil reaction exceeds a pH of 8.0, the availability of some essential nutrients is limited (Figure B1). Most nutrients exhibit optimum availability in a pH range of 6.0 to 7.5. Nutrient availability sharply decreases above pH 8.0 as some nutrients become less soluble. Under these conditions, a soil acidifying agent is used to adjust the pH into the 6.5 to 7.0 range. From the analytical results of the soil samples collected by WES personnel in Honduras, none of the sites require this treatment. One soil sample taken at Palmerola did exhibit a pH above 8.0, but the WES investigators feel that the pH will drop into the acceptable range once the wet season begins.

4. Soil salinity is the final factor in soil fertility. A soil can be fertile in all other respects, but most plants will not survive if the soil is high in soluble salts. Soil salinity is determined by the measurement of the electroconductivity of a soil extract solution. Based on WES analysis of the soil samples obtained, no soil salinity problem exists at any of the sites.

5. Seedbed preparation is an important step for the successful vegetation establishment. Included in seedbed preparation are fertilization, liming, and tillage. Fertilization should be performed prior to seeding when practical. Fertilizer and lime are more efficiently used when incorporated into the soil. Lime is most effective when it is applied and incorporated

into the soil 4 to 6 months prior to seeding. When a hydro-mulch machine is to be used to sow the seed, liming should be performed separately from seeding and fertilization. Tillage is the final step in seedbed preparation, but it is often performed concurrently with fertilizer incorporation. Tillage loosens compacted soil and improves soil tilth, destroys weeds and other competitive plants, and increases the moisture-holding capacity of the soil. In hydro-mulch seeding operations, tillage should be performed if time and slope permit. A harrow is adequate for tillage performed on lightly compacted cut and fill slopes. On more compacted soils, a disk is necessary. If a soil is very compacted or is known to have impervious hardpans at shallow depths, a subsoiler or chisel plow should be used to perform the initial tillage operation. Under all situations, tillage will improve seedling establishment.

6. Sowing the seed is the final step in vegetative establishment. Seed can be sown using a drill or broadcast (hydro-mulching is essentially the same as broadcast). Drilling the seed reduces the amount of seed required to be sown per acre, but requires more expensive equipment and a more highly skilled operator than does broadcasting. Seed germination is improved when drilled because of better soil-to-seed contact, which results in less seed desiccation. Germination of broadcast seed is improved if the field is rolled with a cultipacker after sowing. The cultipacker improves soil to seed contact. When it is not possible to drill or cultipack seed, a mulch is useful in improving vegetation establishment. Mulches can be of hay, straw, peat, or wood fiber. If hydro-mulching is to be performed, the mulch selected for use should be compatible with the machine being used.

7. The rate at which seed should be sown is determined by the size and weight of the seed, the desired plant density, and the seed's germination percentage. Seeding rates can also be adjusted for the growing conditions and sowing method. When sowing seed on steep slopes or highly erosive soil, the seeding rate should be increased to compensate for expected seed loss and to increase the plant density. Increasing the seeding rate 2 to 4 times the recommended seeding broadcast rate is an accepted practice when establishing vegetation under severe conditions. Seed cost is generally the least expensive component of vegetation establishment. As mentioned in the previous paragraph, broadcast seeding rates are higher than drilled rates. Seeding rates for hydro-mulching can be reduced from the rate recommended for broadcasting if a mulch is used; if no mulch is used, then the recommended

broadcast rate applies. Each lot of seed should be tested for germination. The seed producer should attach a tag to the seed bag with information on the percent germination of the seed. Since germination can vary greatly, seeding rates should be increased if percent germination is less than 90 percent.

8. The saying, "Timing is everything," is applicable to successful vegetation establishment. When all the environmental factors are at their optimum, it is the proper time to sow seed. Two factors yet to be discussed are temperature and moisture. Temperatures favorable for germination and seedling establishment generally exist year-round in Honduras. Moisture is the critical factor in determining when to sow seed. Because Honduras has distinct wet and dry seasons, it is relatively easy to determine the optimal planting time. Seeding should begin 1 to 2 weeks before the start of and be completed not less than 3 months before the end of the wet season. If a humectant is used in conjunction with hydro-mulching, seeding can begin earlier than 1 to 2 weeks before the beginning of the wet season. However, a humectant cannot be depended on to supply the quantity of water necessary for a growing plant. Therefore, if the site is seeded too far in advance of the wet season, vegetation establishment may fail because of a lack of available water to meet plant demands.

9. Periodic maintenance of the vegetation will be necessary to maintain a good stand of plants. The level of maintenance will be site specific and will be influenced by land use. Without maintenance, the vegetation cover can be expected to change over time, e.g. decrease in plant density, invasion by undesirable species, or ecological succession. These changes can also occur when the vegetation is maintained, but the changes will be more gradual. Maintenance can range from periodic burning to fertilization to mowing. Burning may be effective along the Fuertes Caminos Road, whereas at Palmerola mowing and periodic fertilization will be required to meet operational needs and to maintain the vegetative cover. Burning or periodic fertilization will be necessary to maintain effective dust control at Jamastran and San Lorenzo if grazing is not permitted; if these areas are grazed, but not overgrazed, little maintenance will be necessary.

Plant Species Recommendations

10. The plant species WES personnel recommended for use in Honduras include some that are indigenous (natural or introduced) and others that are found in the United States growing under similar climatic conditions. Not every species listed will perform well at every site; some may have a very limited range of use, while others will perform satisfactorily at all sites. A mixture of species should be sown at each site for the best results, except where noted in the individual site recommendations.

11. A brief description of each plant species, including area of adaptation and seeding rate, follows. Species suitable for use at each site are presented in Table B1. The rationale used to determine the species recommended for a particular site are given in Table B2.

Bluebunch wheatgrass
(*Agropyron spicatum*)

12. Bluebunch wheatgrass is a cool season perennial bunchgrass that grows on a wide range of soil textures. It is intolerant of high water tables, poor drainage, and early spring flooding, but exhibits moderate drought tolerance and fair fire tolerance. Stands of bluebunch wheatgrass establish slowly, making it unsuitable for inclusion in mixtures containing aggressive species. Seeding rate is 10 lb of pure live seed (PLS)/acre if drilled and 20 lb PLS/acre if broadcast. When planting with a drill seeder, the seeding depth should be set to 1/2, 1/4, 3/4 in. on loamy, clayey, and sandy soils, respectively.

Redtop (*Agrostis alba*)

13. Redtop is a cool season, open sod-forming grass that spreads by rhizomes. It is adapted to all types of soil in humid regions having 20 to over 40 in. of mean annual precipitation (MAP). Redtop tolerates moderate acidity and grows well on infertile soils. It exhibits a fair tolerance toward soil salinity, drought, and fire. Seedlings are vigorous, and established plants are moderately competitive. Redtop is seeded at the rate of 8 to 10 lb PLS/acre. If drilled, it should be sown not more than 1/2 in. deep; if broadcast, seed should be cultipacked.

Table B1

Plant Species Recommendations for Each Site*

Plant Species	Fuertes Caminos	JTF Bravo/ Palmerola	San Lorenzo	Jamastran
Cynodon dactylon	p	x	x	x
Cynodon plemphemefa	p	x	x	x
Lespedeza	p			
Agrostis alba	x			
Schizachyrium scoparium	x	p		
Bromus	x	a		
Eragrostis curvula	x	x	x	x
Eragrostis	x	x	x	x
E. lehmeriana	x	x	p	p
Festuca	x	a		
Festuca	x	a		
Leptochloa	x	x	x	x
Poa	p	a		
Sesbania		p	x	x
Setaria	x	b	x	x
Sesbania	x	x	x	x
Melilotus alba	x	x	x	x
Melilotus officinalis	x	x	x	x
Dahlgrenia	x	x	x	x

(Continued)

* p = probably suitable for use at this location.
x = suitable for use at this location.
a = suitable for use only in areas where supplemental water can be applied.
b = capable of growing at this location, but not suitable for general use; species may be used in special applications.
c = suitable for use at this location, but seedlings should be planted.

Table B1 (Concluded)

Plant Species	Fuertes Caminos	JTF Bravo/ Palmerola	San Lorenzo	Jamastran
Plantago indica	x	x	x	x
Rhynchelytrum repens	x	b		
Atriplex La serena	x	b	x	x
Pinus ocarpa	x	c	c	c
Cerecidium microphylla	x	c	c	c
Acacia constricta	x	c	c	c
Cassia stuarti	x	c	c	c
Acacia cavenia	x	c	c	c
Madina boreua		c	c	c
Eucalyptus camaldulensis		c	c	c
Acacia mangium		p/c	c	c
Casurina equitsetifolia		p	p	c
Pinus caribaea	x	c	c	p
Eucalyptus globulus		c	c	c
Prosopis juliflora velutina		c	c	c
Cuppressus spp.	p	p		

Table B2

Criteria Used in Determining Recommended Species for Each Site

Site	Climatic Adaptation	Erosion Control	Sod Forming	Drought Tolerance	Salinity Tolerance	Palatability	Maintenance Requirements
Fuertes Caminos Road	x	x	x	x			x
JTF Bravo/ Palmerola:							
Airfield area	x		x	x			x
Cantonment area	x		x	x			
San Lorenzo	x			x	x	x	x
Jamastran	x			x		x	x

Little bluestem
(*Schizachrium scoparium*)

14. Little bluestem is a warm season, long-lived perennial bunchgrass that is semisod forming. It is tolerant of a wide range of soil textures when adequate moisture is available. Little bluestem has good cold tolerance, moderate drought tolerance, moderate shade tolerance, and good fire tolerance. Seedling vigor is weak. Seeding rates are 4.5 lb PLS/acre when drilled and 9 lb PLS/acre when broadcast. Drill seed 1/4 in. deep on fine-textured soils and 3/4 in. deep on coarse-textured soils. Several improved varieties of little bluestem are available; Pastura is the variety most likely to succeed in Honduras.

Smooth brome (*Bromus inermis*)

15. Smooth brome is a cool season perennial sod-forming grass that spreads by rhizomes. It thrives in fertile, deep silty and clayey soils, but performs poorly on sandy and dense clay soils. Smooth brome's shade and fire tolerance is moderate and fair, respectively. Seeding rates are 7 lb/acre drilled and 14 lb/acre broadcast. Seeding depth is 1/2 to 1 in. deep.

Weeping lovegrass (*Eragrostis curvula*)

16. Weeping lovegrass is a warm season perennial bunchgrass which has an extensive fibrous root system that is very effective in stabilizing potentially erosive soils. It grows in a wide range of soil textures in regions receiving between 20 and 40 in. MAP. Weeping lovegrass is an excellent grass for use on highly acidic or strongly alkaline soils. It will grow to elevations of 7,000 ft, which includes all but the highest peaks in Honduras. Weeping lovegrass is tolerant of annual burning in its dormant state and at the beginning of its growing season. It is a strongly competitive grass with moderate shade tolerance. Because of its competitive nature, weeping lovegrass is included in mixtures at very low seeding rates. Seeding rates for pure stands are 1 lb/acre drilled 1/4 to 1/2 in. deep, and 2 lb/acre broadcast. When included in mixtures, it should be used at the rate of 1/2 to 1 lb/acre broadcast.

Lehmann lovegrass
(*Eragrostis lehmanniana*)

17. Lehmann lovegrass is a warm season perennial sod-forming bunchgrass. It is similar to weeping lovegrass, but is shorter and more drought tolerant. Seeding rates are the same as for weeping lovegrass.

Cochise lovegrass
(*E. lehmanniana X E. trichophora*)

18. Cochise is a hybrid lovegrass. It is a robust warm season perennial bunchgrass. It is adapted to sandy and silt loam soils, but not suitable for use on heavy clay soils. It is drought tolerant, but performs better at higher elevations (between 1,500 and 6,000 ft). Seeding rates are the same as for weeping lovegrass.

Tall fescue (*Festuca arundinacea*)

19. Tall fescue is a cool season bunchgrass that is moderately sod-forming. It is tolerant of all types of soil textures and of moderate soil acidity. Tall fescue has fair drought tolerance and is fire tolerant in its dormant state. Seeding rates are 8 lb/acre drilled 1/4 to 1 in. deep and 15 lb/acre when broadcast.

Creeping red fescue (*Festuca rubra*)

20. Creeping red fescue is a cool season sod-forming grass that is adapted to a wide range of soil textures. It is tolerant of saline and low-fertility soils. Seeding rates are 10 lb/acre when sown in a pure stand and 5 lb/acre when included in a mixture.

Green sprangletop (*Leptochloa dubia*)

21. Green sprangletop is a short-lived, medium-tall, warm-season perennial bunchgrass. It flourishes in deep sandy soils, but is adapted to rocky hillsides. The greatest benefit of green sprangletop is that it establishes very quickly, although it is not very competitive. It is very tolerant of drought and tolerates weakly saline and moderately alkaline soils, but is intolerant of shade. Establishment of this grass would be enhanced if seeded with a hydro-mulching machine. Seeding rates are 1 lb/acre drilled 1/2 to 3/4 in. deep and 2 lb/acre broadcast.

Kentucky Bluegrass (*Poa pratensis*)

22. Kentucky bluegrass is a cool season, sod-forming perennial grass. It is adapted to a wide range of soil textures, but grows best on sandy to clayey alluvial soils. Fairly drought tolerant, Kentucky bluegrass is intolerant of burning. It tolerates weakly acid, basic, and saline soils and is moderately tolerant of shade. Establishment is improved when supplemental mulch is added. Seeding rate is 1 to 3 lb/acre. If drilled, it should be sown 1/4 in. deep.

Alkali sacaton (*Sporobolus airoides*)

23. Alkali sacaton is a warm season bunchgrass that thrives on moist sandy to clayey textured soils. It is tolerant of saline, saline-sodic, and alkali soils. The grass is tolerant of poor drainage, has moderate drought and fire tolerance, and has fair shade tolerance. It should be sown when soil temperatures average 80° to 90° F and precipitation is expected within 15 days. Establishment is improved if sown with a hydro-mulching machine. Seed should be broadcast at the rate of 0.4 lb/acre or drilled 1/4 in. deep at the rate of 0.2 lb/acre.

Cicer milkvetch (*Astragalus cicer*)

24. Cicer milkvetch is a spreading, warm-season, leguminous perennial forb. It is adapted to a wide range of soil textures. Established stands have moderate drought tolerance. Cicer milkvetch is tolerant of weakly acidic and strongly alkaline soil conditions. It is very competitive and should be sown only with a grass of similar competitiveness (tall fescue, smooth brome, or weeping lovegrass). Seed should be inoculated before sowing to receive the nitrogen-fixing benefit of milkvetch. Seed should be sown at the rate of 5 lb/acre in a mixture with a grass.

Buffelgrass (*Cenchrus ciliaris*)

25. Buffelgrass is a warm-season, perennial, sod-forming bunchgrass that is found on sandy and medium-textured soils. It is drought tolerant, but cold sensitive. Buffelgrass is moderately salt tolerant. Seeding rates are 3 lb PLS/acre in a pure stand and 2 lb PLS/acre in a mixture.

White sweetclover (*Melilotus alba*)

26. White sweetclover is a short-lived perennial legume that tolerates drought, salinity, and alkalinity. It requires inoculation to get maximum benefit from nitrogen fixation capability. It should be sown at the rate of 10 to 15 lb/acre in a pure stand or 2 to 8 lb/acre in a mixture.

Yellow sweetclover
(*Melitotus officinalis*)

27. Yellow sweetclover has the same characteristics and seeding rates as white sweetclover.

Sainfoin (*Onobrysis viciaefolia*)

28. Sainfoin is a long-lived perennial legume. It is drought and alkaline tolerant and performs well on soils of all textural classes. Sain-

foin is seeded at the rate of 35 to 45 lb/acre in pure stands and 20 to 25 lb/acre in a mixture.

Bermudagrass (*Cynodon dactylon*)

29. Bermudagrass is a long-lived, perennial, sod-forming warm-season grass. It will grow on soils of all textures and is tolerant of acid, saline, and alkaline soils. Bermudagrass is very aggressive and is not compatible with most other species. Common bermudagrass is propagated by seed; however, virtually all of the improved varieties are propagated vegetatively. Bermudagrass is indigenous to Honduras.

Star grass (*Cynodon alemfuensis*)

30. Star grass is a perennial, warm-season grass. It is more aggressive than bermudagrass and grows taller. It was introduced into Honduras and grows well under most climatic conditions throughout the country. It may not be suitable for use in the higher elevations. Star grass is vegetatively propagated. Normally, a field of Star grass is cut, and the cuttings are collected and transported to the field to be established. There, the cuttings are spread on the ground and crimped into the soil. The crimped cuttings will root in a few days if moisture is adequate, and in a few weeks, the new field will be established.

31. A number of other plant species can be included in seed mixtures designed for revegetation use. Among them are the following:

a. *Plantago indica*, an annual that establishes quickly.

b. *Rhynchelytrum repens*, a perennial grass that exhibits a mounding, spreading habit of growth. It is not suitable for use around airfields.

c. *Atriplex La serena*, a perennial ground cover that exhibits a spreading habit of growth and forms an extensive root system.

d. *Pinus ocarpa*, a pine tree found naturally occurring in Honduras. Needs to have mycorrhizae added to it when sown or planted on fill embankments.

e. *Cercidium microphylla*, a wide-spreading tree that grows to 12 ft. It is generally found on gravelly or coarse soils.

f. *Acacia constricta*, a small thorny tree that is tolerant of drought, heat, and a wide range of soil conditions.

g. *Cassia stuarti*, a spreading evergreen shrub that grows 6 to 8 ft high. It forms an extensive root system that effectively anchors the subsoil.

h. *Acacia cavenia*, a deep-rooted, perennial shrub that forms an extensive root system, with roots penetrating to as deep as 30 ft. It is a leguminous shrub that will supply associated species with nitrogen.

APPENDIX C: WINDBREAK DESIGN

1. Windbreaks are structures that reduce wind velocities, providing a shelter for a fixed distance on their leeward side. US Army Engineer Waterways Experiment Station (WES) personnel recommend that windbreaks be constructed near the airfields as part of the dust-control plan. The most economical windbreak is one constructed of trees and shrubs.

2. Soil is moved by the wind in three ways: creep (7 to 25 percent), saltation (50 to 80 percent), and suspension (40 percent). Saltation occurs when soil particles bombard each other, causing the particles to skip across the soil surface. Since the majority of soil movement by the wind is related to the velocity of the wind, reducing the velocity of the wind will result in a reduction of soil movement, or for these purposes, a reduction in dust.

3. Windbreaks reduce wind velocities in two directions, windward and leeward. The reduction in wind velocity on the windward side of the windbreak is effective for a distance of 2 to 5 times the height of the tallest tree species. On the leeward size, the effect is more dramatic. Wind velocities are reduced for a distance of 30 to 40 times the height of the tallest tree species. For design purposes, the Soil Conservation Service (SCS) requires that windbreaks protect the leeward side a distance of 10 times the height of the tallest tree species.

4. Based on WES observations of the conditions in Honduras, WES personnel recommend that for the airfield areas a planning factor of 5 to 7 times the height be used if aircraft safety requirements are met. This reasoning is based on the need for a quick effect. The SCS requirement is based on the height of the tallest tree species at 20 years of age. WES reduced the factor to enable the effectiveness of the windbreak to be used earlier. The WES factor will result in the trees being planted closer to the runways and the use of tree species that will reach a height of 25 to 30 ft within 5 years. This will require that the windbreak be placed 125 to 210 ft from the runway surface on the windward side of the runway. At Palmerola, additional windbreaks will be needed to reduce the dust in the cantonment area.

5. There are two primary types of windbreaks, field and farmstead. The field windbreak is designed to protect agricultural soils from wind movement. It is readily adapted to airfield use without major modifications.

The farmstead windbreak is designed to protect homes and farm buildings. It is adaptable for use near and in the cantonment area at Palmerola.

6. Variations of the field windbreak are useful for controlling dust and wind. The twin-row, high-density windbreak (Figure C1) is useful where dust control is the primary concern. In this windbreak, trees or shrubs of the same species are planted in rows 6 ft apart on-center. Twin rows of different species are planted between 25 and 50 ft apart, depending upon species characteristics. The tallest species is planted in the middle twin rows. When protection from crosswinds is desired, a single-row windbreak is used. A single row of trees is planted parallel to the area to be protected (Figure C2). Protection against both wind and dust is provided by the two-row windbreak. In this windbreak, two species of trees are used: a coniferous evergreen on the windward side and a broadleaf deciduous or evergreen on the leeward side (Figure C3).

7. The twin-row, high-density windbreak is also suitable for use as a farmstead windbreak. In this application, however, a buffer zone of approximately 150 ft (measured from the outside row of trees on the windward side of the windbreak to the windward edge of the building to be protected) is required for maximum effectiveness. The buffer zone permits air circulation to take place in the vicinity of the building and provides for cooling breezes to be active while preventing the full effect of strong winds (Figure C4).

8. Windbreaks do not have to be planted in straight rows to be effective. However, there are some techniques that enhance the effectiveness of windbreaks. The ends of the windbreak should be extended perpendicular to the main windbreak for a minimum of 75 ft to prevent winds from skirting around the ends of a straight windbreak and producing eddies (Figure C5). The ideal shape for a windbreak is "L" shaped (Figure C6). Windbreaks can be constructed in a serpentine fashion to go around obstacles; however, maintaining the continuity of the windbreak is vital to its effectiveness (Figure C7). Breaks or gaps in the windbreak should be filled. Roads through the windbreak should be angled to prevent winds from flowing through the gap (Figure C8). If gaps are perpendicular to the windbreak, the velocity of the wind through the gap often exceeds the velocity of the unbuffered wind on the windward side. When it is not practical to reposition a road or other gap, a small separate windbreak should be constructed opposite of and as close to the gap as possible (Figure C9). In this situation, WES personnel recommend that the

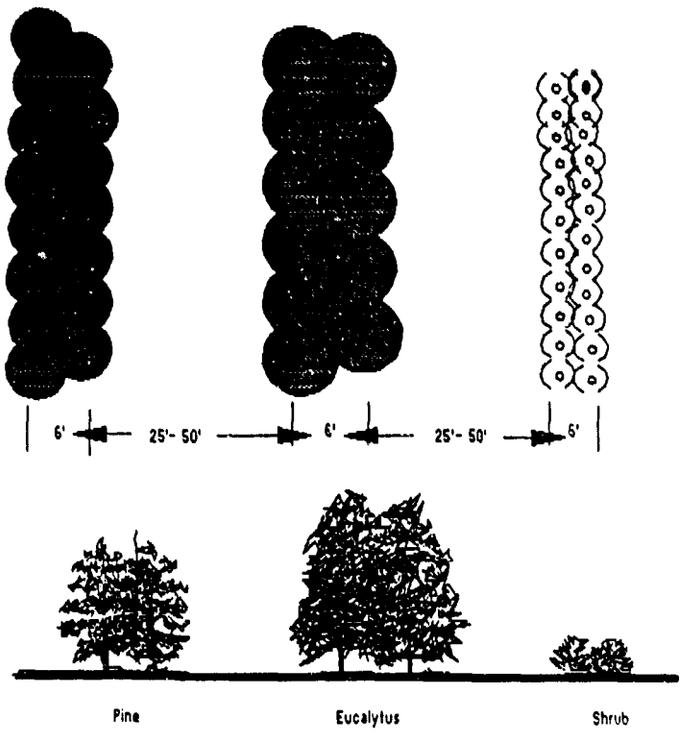


Figure C1. Twin-row, high-density windbreak

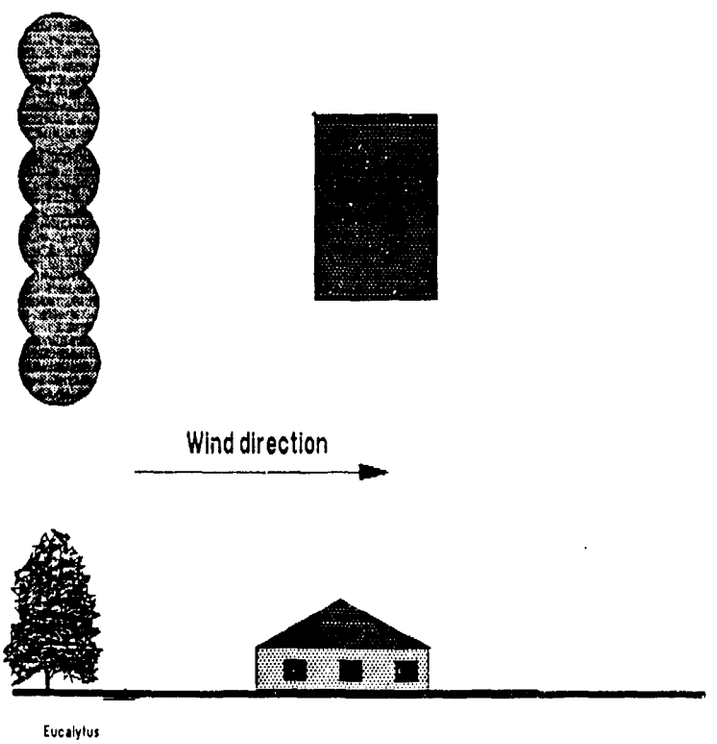


Figure C2. Single-row windbreak

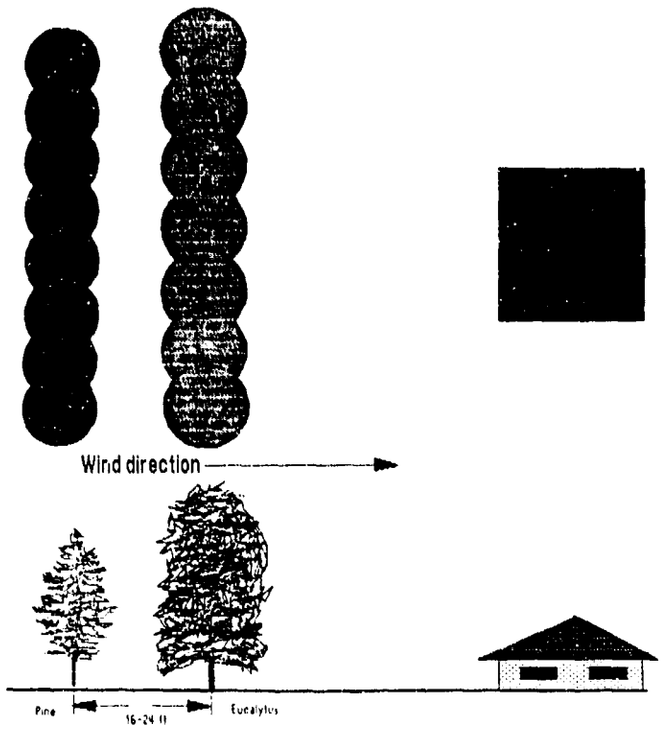


Figure C3. Two-row windbreak

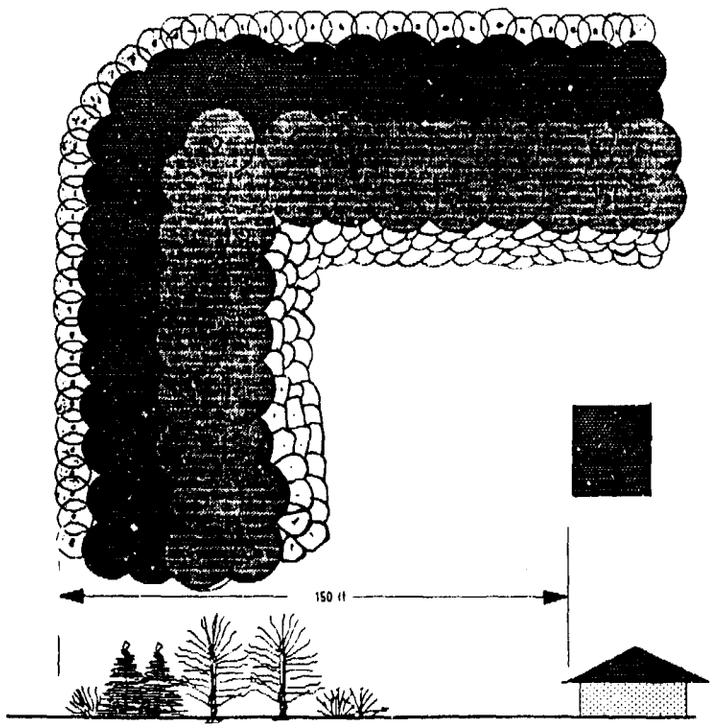


Figure C4. Buffer zone

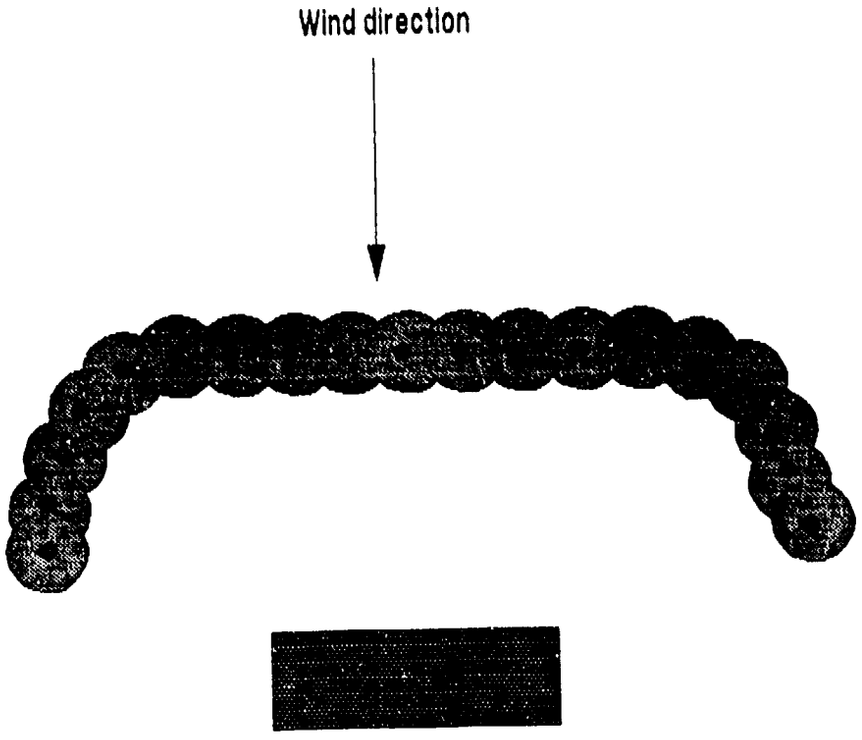


Figure C5. Windbreak ends

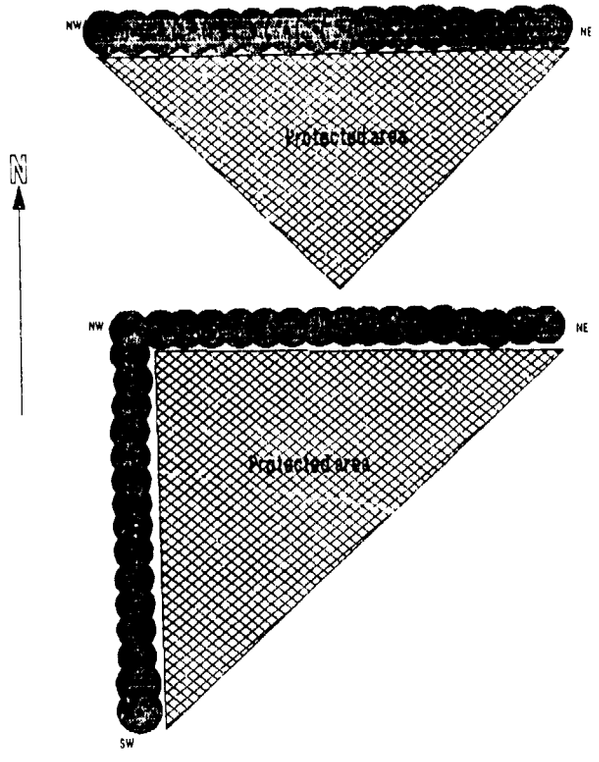


Figure C6. Protected area provided by windbreaks

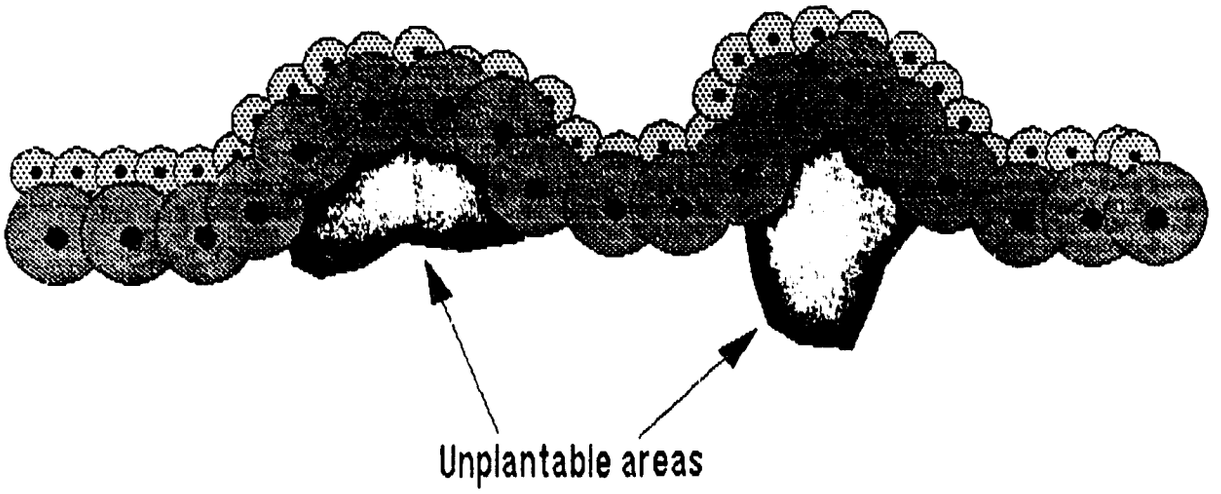


Figure C7. Windbreaks around obstacles

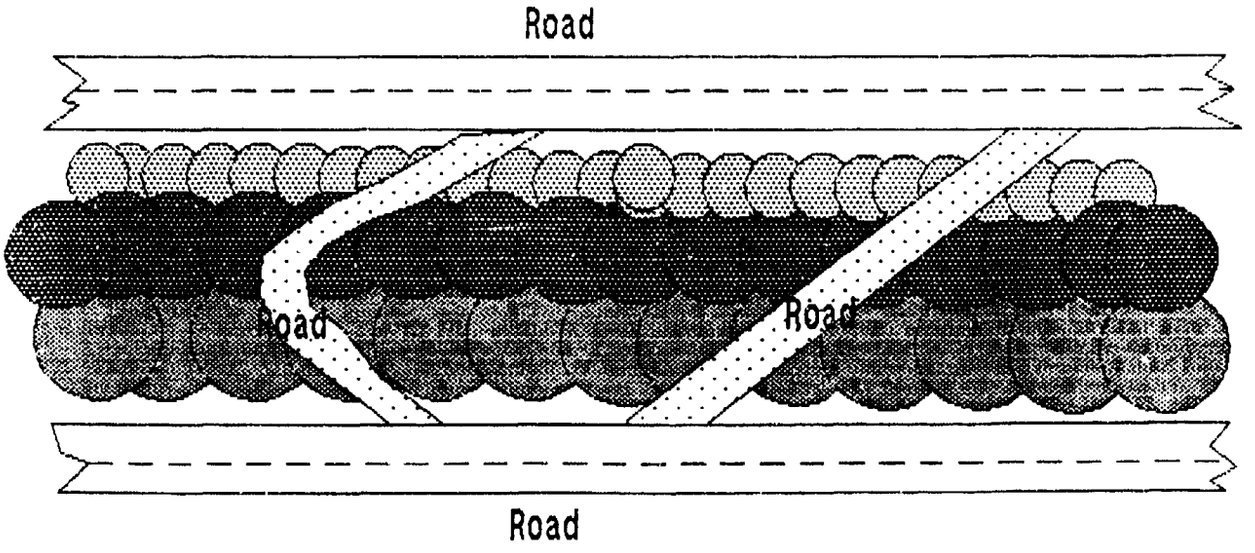


Figure C8. Roads through windbreaks

stopgap windbreak extend 2.5 times the distance of the gap in either direction, measured from the center of the gap.

9. The tree and shrub species to be planted for windbreaks will vary by location, but the general recommendations of WES investigators are:

a. *Moringa borana*. This shrub attains a terminal height of 5 m and is suitable for use as the shrub component in all airfield locations discussed in this report.

b. *Eucalyptus camaldulensis*. This tree is very fast-growing (2 to 5 m/year) and drought-tolerant. It is recommended for use at Palmerola and San Lorenzo, and it is also suitable for use at Jamastran.

c. *Acacia mangium*. This fast-growing tree having a terminal height of 50 ft is recommended for use at Jamastran.

d. *Casuarina equisetifolia*. This species is also recommended for Jamastran.

e. *Pinus caribaea*. This species may be suitable for use at San Lorenzo. Its adaptation to the region is questionable, but its successful establishment is likely.

f. *Pinus oocarpa*. Known as ocote pine, this species is naturally occurring in Honduras. It is appropriate for use along the Fuertes Caminos Road.

g. *Eucalyptus globulus*. Similar to *E. camaldulensis*, this species is suitable for use at the same locations.

h. *Prosopis juliflora velutina*. Known as velvet mesquite, this is a drought-tolerant tree that grows to 30 ft. It is suitable for use at any of the locations discussed this report.

i. *Cupressus* spp. Known as Arizona cypress, this species is suitable for use at higher elevations. It is likely to succeed at Palmerola and along the Fuertes Caminos Road.

10. The windbreak systems recommended by WES personnel use evergreen shrub species, *M. borana* or velvet mesquite; broadleaf evergreen tree species, *E. camaldulensis*, *E. globulus*, *A. Mangium*, or *C. equisetifolia*; and coniferous evergreen tree species, Caribbean pine, ocote pine, or Arizona cypress. Spacing of these species within the windbreak will vary relative to the type of windbreak being constructed.

a. Twin-row high-density windbreak. All species within a twin row will be planted on 6-ft centers. Shrubs within the same row will be spaced at 4 ft apart. Broadleaf evergreens within the same row will be spaced 6 to 8 ft apart. Coniferous evergreens within the same row will be spaced 6 ft apart. The arrangement of the shrub and tree rows will be shrub-broadleaf evergreen, tree-coniferous evergreen tree from windward to leeward side of the windbreak, respectively.

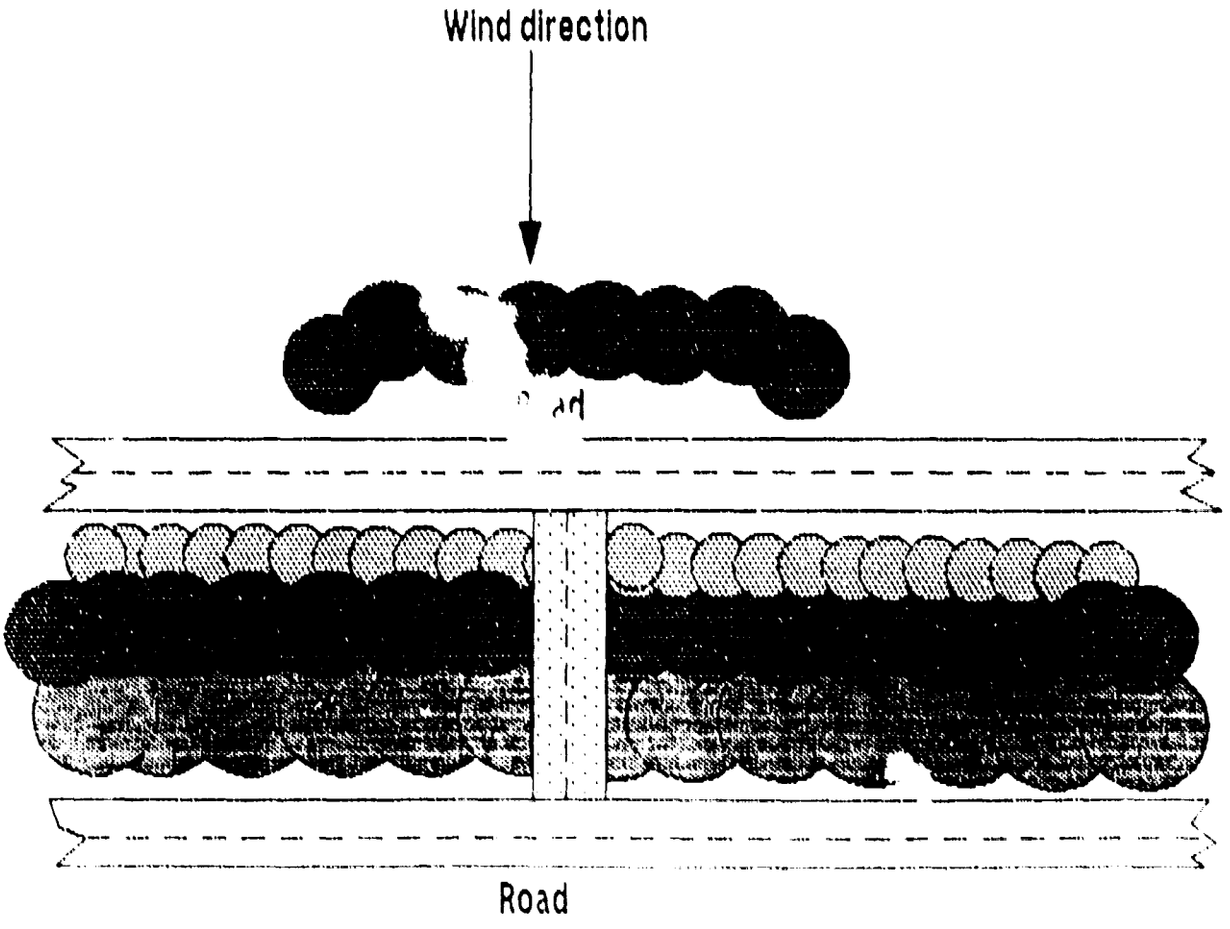


Figure C9. Windbreak with perpendicular gap

b. Single-row windbreak. Using the broadleaf evergreen species, a single row of trees is planted parallel to the area to be protected. Trees should be spaced 8 to 12 ft apart within the row.

c. Twin-row windbreak. Two single rows of trees are planted parallel to each other. Spacing between the rows is 16 to 24 ft. A coniferous evergreen species is planted in the windward row with individual trees spaced 8 to 10 ft apart. The leeward row is composed of broadleaf evergreens spaced 10 to 12 ft apart.

11. Establishing a successful windbreak requires more than careful planning and placement of the trees and shrubs. Proper handling of seedlings and preparation of the site are essential components for establishing a successful windbreak. Prior to planting, the soil should be tilled to loosen the soil and reduce competition from weeds and other plants. On steep slopes where tillage is impractical or unsafe, chemical control of weeds and other

plants should be used. Correcting soil nutrient deficiencies will promote rapid establishment and seedling survivability.

12. When seedlings arrive from the nursery, they should be handled with care. If the seedlings cannot be planted immediately, they should be stored in a cool area and the roots inspected for dryness periodically. If the roots appear dry, they should be moistened with water. Seedlings can be stored in this manner for several days. If planting cannot be scheduled for a week or more after the seedlings are received, they should be "heeled in." To heel the seedlings in, a trench is dug deep enough and wide enough to hold the roots without crowding. The seedlings are placed into the trench, and the roots are moistened. The roots are covered with soil, sawdust, wood chips, or mulch and packed firmly to remove any air pockets. The material covering the roots should be kept moist.

13. When it is time to plant, the planting rows should be marked with flags or stakes before the seedlings are removed from cool storage or the trench is heeled in. The trees are removed from the storage or trench and immediately placed in buckets partially filled with water. Seedlings should not be left in water for longer than 6 hr, or seedling death will result. Care should be taken to prepare only the number of seedlings that can be expected to be planted in a 4- to 6-hr period.

14. Planting can be done either by machine or by hand. Whichever method is used, it is important that the opening in the soil be made large enough to receive the entire root system without bending or crowding. A hole too shallow that causes the roots to be turned up at the bottom will result in the death of the seedling. The seedling should be planted to approximately the same depth it stood in the nursery. It should be easy to see the mark made by the soil. The seedling should not be planted too deep or too shallow; a good rule of thumb is to plant 1 in. or less deeper than the soil mark. The hole is then filled in, and the soil is packed firmly around the seedling with one's foot.

15. Control of weeds and other vegetation around the seedlings is necessary during the first few years after planting. During this period, the tree's roots are very near the surface, and competition for water and nutrients may reduce the tree's rate of growth or increase its chances of dying during drought conditions. Cultivation or chemical control can be used, but both must be used with care to prevent damage to the young trees.

Periodic fertilization will promote rapid growth and the development of sound, healthy trees.

APPENDIX D: SOIL ANALYSIS REPORTS

Soil samples were collected at each of the sites discussed in the main text of this report. Soils were randomly sampled, and three or more samples were obtained at each site. The soil samples were stored in plastic bags and transported to the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, where they were dried and ground to pass a 2-mm mesh sieve. Analysis of the soil samples was performed by DeltaLab, Vicksburg, MS, under a purchase order issued by WES. WES personnel reviewed the results of the analysis and have concluded that the data accurately represent the actual soil fertility status of the soils analyzed. The results of the individual soil samples follow.

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REPORT NO: 880531-5 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: UPPER 12' CUT AT FUERTES CAMINOS

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
5.5	38.4 H	1.3 L	153 H+	1475 S	243 S	223 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ 100G
44 H	6 H	0.9 L	0.18 L	0.38 L	25 L	17.4:

CODE: L=LOW M=MEDIUM H=HIGH H+=EXCESSIVE S=SUFFICIENT

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 3.0 MIN (TO PH 6.0): 1.5

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/YEAR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

BY: SPF

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ENV LAB-WES
VICKSBURG, MS 39180

REPORT NO: 880531-10 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: SECTION BT 87

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
5.8	11.1 L	12.3 L	186 H+	2273 S	252 S	300 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
79 H	53 H	3.1 H	0.02 L	0.17 L	11 L	17.14

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 1.0 MIN (TO PH 5.0+): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 30 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/A/YR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

BY: _____
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REPORT NO: 880531-3 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: EAST SIDE/NORTH END OF RUNWAY/PALMEROLA

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
8.4	0	6.5 L	267 H+	4278 S	493 S	508 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
91 H	143 H	1.8 H	0.99 H	0.94 M	62 M	28.39

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 5.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 30 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/YEAR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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REPORT NO: 880531-2 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: JAMASTRAN SOUTHSIDE OF PARKING(BERMUDA)

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
7.4	0	58.4 H+	316 H+	3531 S	412 S	262 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ 100G
411 H	208 H	4.3 H	1.02 H	2.23 H+	146 H+	23.04

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 5.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS NITROGEN PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 60 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS NITROGEN ANNUALY. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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REPORT NO: 880531-7 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: JAMASTRAN WEST END NEAR TAXIWAY MIDPOINT

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
7.6	0	69.8 H+	258 H+	4211 S	479 S	453 H+

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
274 H	178 H	2.5 H	0.79 H	1.48 H	97 H	27.68

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS NITROGEN PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS OF NITROGEN PER YEAR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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REPORT NO: 880531-12 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: MOONDUST (LOOSE FROM COT) SECTION 2

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
5.3	33.0 H	3.9 L	190 H+	1707 S	230 S	233 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
50 H	11 H	1.5 M	<0.01 L	0.71 M	47 M	17.85

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 3.0 MIN (TO PH 6.0): 1.75

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P205 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P205/A/YR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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VICKSBURG, MS 39180

REPORT NO: 880531-11 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: PALMEROLA 042688 CHINOOK NORDS SRAR OR ETC.

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
6.8	0	34.1 H	447 H+	3522 S	331 S	204 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
253 H	219 H	8.9 H	0.63 H	2.68 H+	189 H+	22.40

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS NITROGEN PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS NITROGEN PER ACRE/YEAR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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VICKSBURG, MS 39180

REPORT NO: 880531-6 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: JAMASTRAN NE CORNER OF AIRSTRIP (BERMUDA)

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
7.0	0	21 M	314 H+	3543 S	857 S	495 H+

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
256 H	215 H	2.8 H	0.95 H	1.95 H+	128 H+	27.81

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 80 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS OF N AND 30 LBS P2O5/YEAR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

BY: _____
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ENV LAB-WES
VICKSBURG, MS 39180

REPORT NO: 880531-15 DATE REPTD: 5-31-88

HORTICULTURAL SOIL TEST REPORT

SAMPLE ID: SAN LORENZO NE CORNER STAGING FIELD NEAR FENCE

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
5.9	17.0 L	3.6 L	180 H+	2340 S	224 S	260 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
310 H	34 H	1.7 H	0.18 L	1.19 H	78 H	18.26

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 1.5 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/A/YR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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TODD HIGGINS
ENV LAB-WES
VICKSBURG, MS 39180

REPORT NO: 880531-1 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: PALMEROLA 042688 SITE FOR NEW UH 60 HANGAR

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
7.7	0	22.3 M	390 H+	2870 S	409 S	277 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
232 H	192 H	4.1 H	1.04 H	1.07 M	70 M	19.96

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 80 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 30 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS N AND 30 LBS P2O5 ANNUALY. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

BY: _____

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TODD HIGGINS
ENV LAB-WES
VICKSBURG, MS 39180

REPORT NO: 880531-16 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: SAN LORENZO NE CORNER STAGING AREA NEAR DITCH

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
5.9	9.4 L	2.5 L	101 H	2239 S	197 S	317 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
214 H	95 H	0.7 L	0.05 L	0.35 L	23 L	15.97

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0.75 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 30 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/A/YR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

BY: SAMUEL P. FAULKNER

DeltaLab

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VICKSBURG, MS 39180

REPORT NO: 880531-8 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: PALMEROLA WEST SIDE OF RUNWAY NORTH END

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
6.6	0	2.8 L	318 H+	3357 S	485 S	349 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
89 H	14 H	1.3 M	0.67 H	1.62 H	106 H	23.16

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/A/YR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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REPORT NO: 880531-14 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: PALMEROLA 042688 WEST PERIMETER FENCE @ BLACKJACK

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
6.7	0	4.7 L	260 H+	3155 S	323 S	243 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
216 H	197 H	2.6 H	0.81 H	1.20 H	79 H	20.19

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/A/YR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

BY: _____
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REPORT NO: 880531-9 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: LOWER 12-24 FT CUT FUERTES CAMINOS

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
5.5	30.4 H	1.9 L	120 H	882 S	445 S	221 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
53 H	9 H	3.0 H	0.23 L	0.46 L	30 L	13.49

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 2.0 MIN (TO PH 6.0): 1.0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 30 LBS N AT PLANTING. THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/A/YR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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VICKSBURG, MS 39180 .

REPORT NO: 880531-4

DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: SAN LORENZO/NW CORNER RUNWAY

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
8.5	0	3.2 L	220 H+	3937 S	517 S	529 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CATIONS MEQ/100G
218 H	102 H	1.6 H	0.35 L	0.18 L	12 L	26.86

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 0 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 30 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/YEAR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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REPORT NO: 880531-13 DATE REPTD: 5-31-88

AGRICULTURAL SOIL TEST REPORT

SAMPLE ID: SAN LORENZO SOUTHSIDE AIRSTRIP

CROP: ROADSIDE TURF FOR DUST & EROSION CONTROL

SOIL TEST RESULTS

EXTRACTABLE LEVELS OF NUTRIENTS

PH	ACIDITY %	PHOSPHORUS PPM	POTASSIUM PPM	CALCIUM PPM	MAGNESIUM PPM	SODIUM PPM
6.3	7.2 L	0.9 L	223 H+	3195 S	635 S	303 H

IRON PPM	MANGANESE PPM	ZINC PPM	COPPER PPM	ORGANIC MTR %	ESTIMATED ORG S PPM	SUM OF CA MG MEQ/100G
53 H	14 H	0.9 L	0.15 L	0.51 M	33 M	24.96

CODE: L=LOW/M=MEDIUM/H=HIGH/H+=EXCESSIVE/S=SATISFACTORY

FERTILIZER RECOMMENDATIONS

LIME REQUIREMENT, T/ACRE : MAX (TO PH 6.5+): 1.0 MIN (TO PH 6.0): 0

FOR ESTABLISHMENT, APPLY 120 LBS N AND 120 LBS P2O5 PER ACRE. INCORPORATE ANY NEEDED LIME INTO TOP 6-8 INCHES PRIOR TO SEEDING. APPLY NO MORE THAN 80 LBS N AT PLANTING, THEN APPLY BALANCE ONE MONTH AFTER SEEDING IF PRIMARY STAND IS BERMUDA OR OTHER GRASS.

FOR MAINTENANCE IN YEARS FOLLOWING ESTABLISHMENT, APPLY 60 LBS EACH OF N AND P2O5/A/YR. RETEST SOIL IN 3 YEARS. ADJUST N RATE AS REQUIRED TO OPTIMIZE GROWTH. IF GRASSES ARE MIXED WITH LEGUMES, REDUCE ANNUAL N RATES BASED UPON PERCENTAGE OF LEGUMES IN STAND.

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