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The Problem of Water in St. Thomas, United States Virgin Islands: A Cultural Ecological Study

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THE PROBLEM OF WATER IN ST. THOMAS, UNITED STATES VIRGIN ISLANDS
A CULTURAL ECOLOGICAL STUDY

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

CHAPTER ONE: THESIS INTRODUCTION

The island of St. Thomas has been home for many cultures over the past thirty-five hundred years, and each society has left its mark on the landscape. This study illustrates the changing relationships between culture and the island environment. It is an attempt to understand how a specific environmental problem has evolved, how a water shortage has come to exist in a relatively wet climatic zone.

Despite fairly regular rainfall, water is shipped daily from Puerto Rico. How can an area that receives close to 50" of rain per year be experiencing a water shortage? Have there been changes in the land-use and vegetative cover which affected the availability of water in St. Thomas and if so, what physical and cultural variables have produced this change?

It is suggested that there is a direct relationship between economic change, land-use, and change in the physical environment. The relationship between land-use and vegetative change, with subsequent changes in hydrology, have been illustrated in many areas throughout the world. Studies by Harris (1966) and Watts (1966), have provided documentary evidence of the human influence on vegetation in the Caribbean islands, with both authors observing successional changes towards a more xeromorphic vegetative cover, and a decline in the water availability. These changes are shown to be a direct result of the clearing of original forest cover, introduction of new species, and land-use activities such as crop cultivation and livestock grazing.

Many studies have been done using an island ecosystem to illustrate

the relationship between changes in the land-use and surface cover to the hydrologic cycle. In such an island ecosystem the boundaries are clear and the ecosystem relatively simple. While studies without these relatively finite boundaries are less common, research done in the continental areas of both the temperate and tropic zones support the relationship between land-use, surface cover, and the hydrologic cycle. For example, I. J. Jackson, in his 1977 study entitled Climate, Water and Agriculture in the Tropics, dedicated a chapter of the book to the human impact on the hydrologic cycle. Both deliberate and inadvertent impacts such as modification of climatic factors, land-use, and modification to surface and groundwater are discussed, and pertinent studies throughout the tropical belt are cited. The author's treatment is admittedly broad, and attention is focused on presenting an outline of work to date, providing a base for more detailed study.

In St. Thomas, studies by Jordan, et al (1972, 1977), Peebles, et al (1979) and Rivera, et al (1970) have provided data on the soil, vegetation and hydrologic change, and have noted a correlation between land-use activities, surface cover, and the hydrologic changes experienced in recent years. This thesis compiles data from these and other reports, identifies the specific cultural and physical variables influencing the hydrologic balance of St. Thomas, and analyzes the reasons for changes in the hydrology.

One common observation of these studies is that the impacts of land-use, while varying in intensity and nature, have a complex and far-reaching effect on the landscape. Bennett, in his introductory chapter of Man and Earth's Ecosystems, noted: "Different lifestyles lead to different cul-

tural landscapes, and the ecological impact of differing lifestyles vary greatly." (1975:53). With this thought in mind, the approach was designed to determine the reason for and process of hydrologic change. The study area has seen many different economies, with varying land-use and subsequent ecological impacts. What part has been played by past and current human systems in influencing the hydrologic cycle of St. Thomas?

E. N. Anderson has written that "the ecological crisis is the result of political and economic structure, specifically the balance of power." (Anderson 1974:272). If this is true, then in analyzing the reasons for a disturbance of an ecosystem, it is necessary to review the evolution of the political and economic structure in that system. This is important because changes in the political and economic structure will be subsequently reflected through changes in land-use. When that change in land-use causes a disturbance in the environment, the culture has three ways in which it might react: it can cease the particular land-use activity, it can adapt the form of land-use to minimize the impact, or, it can ignore the problem and the environment will continue to deteriorate. When the pace of change is rapid, the ecosystem is unable to adapt to disturbances because the culture itself is changing too rapidly to appreciate the disruption, reform the system, and evolve adequate adaptive responses. This ability to appreciate the cause and effect of environmental disturbance is a crucial factor in the culture's capability to survive and sustain its role in the ecosystem. Because of the rapid pace of change in the political and economic structure, the

culture is limited in its response to environmental stress and has, therefore, lost its flexible nature. The inability to perceive or rectify the continuing deterioration of the environment will then result in an ecological crisis.

An example of this model is illustrated by the introduction of new cultures into a geographic region. The settlement of California by the Spanish involved the establishment of a missionary system. The political and economic structure of humans in California changed from a small scale hunting and gathering society to a class hierarchy of priests, soldiers, and settlers, with mission Indians at the bottom of the structure. With this change came an introduction of new forms of land-use practices. Ranching and agriculture became prevalent in the Spanish settled areas. Within a few years, introduced European grasses, brought over as livestock feed, outcompeted the native plants and, after three hundred years, only a few areas in the state contain the original composition of native grasses. In this case, the cause of biologic change can be traced to a specific cultural activity, which, in turn, is tied to political and economic change. (Dasmann 1975:59-74).

Another illustration of this model can be seen in the Irish potato famine of the 1870's. While the widespread potato blight resulted in a famine in the 1850's, due to the local habits of cultivation and a failure of the rulers to instruct or permit a change in the cultivation habits, the potato blight again spread through most of Ireland in the 1870's and lasted several seasons. The failure to comprehend the limits of the existing agricultural system, despite an earlier famine, and to evolve an adequate adaptive response insured the success of the later

potato blight fungus. In this case a culture firmly entrenched in its traditions was unable to accurately evaluate a biologic threat, and the result disrupted the cultural system. (Bennett 1976:199).

Cultural ecology locates biological and environmental factors in the framework of a concrete socio-historical process. (Bennett, 1976: 199). The theoretical model previously given is used as a general framework for the cultural ecological study of the past and current systems and their influences on the hydrological balance of St. Thomas. In order to define the problem, illustrate the process of change, and determine the impetus for change, it is necessary to incorporate not only biological and environmental factors, but socio-historical analysis as well. The emphasis in this study is on determining the connection between socio/economic change, land-use practices, landscape changes, and ecosystem disturbances.

This thesis begins with a description of the physical landscape and a discussion of the hydrologic cycle in order to clearly demonstrate the relationship between land-use, landscape change, and changes in the hydrologic cycle. Before the cause of environmental change can be determined, it is first necessary to define precisely what change has occurred.

In the second section a historical overview is given, focusing on the cultural change from a simple, self-sufficient economy to one that is totally dependent upon extrinsic factors to survive. This section includes chapters on prehistoric, historic and recent times and is oriented towards determining both internal and external factors responsible for economic and political change, and their subsequent impact on land-use and landscape change. Conclusions of this thesis are presented

in the final chapter, in which the impacts of land-use on hydrology are summarized, reasons for land-use change are suggested, and the possibility of a return to the natural hydrologic balance is discussed.

The site selected for this study is the island of St. Thomas. It is located 18° North of the Equator, 64° West of Greenwich and 40 miles East of Puerto Rico. Rising from sea level to a height of 1550 feet, the island encompasses 28.25 square miles. It is easily distinguished from neighboring islands by its high ridge system and many bays that indent the coast.

One of a chain of hundreds, the island is a stepping stone in the Caribbean and belongs to the furthest north group of islands. This location of St. Thomas has long been of cultural importance. North and South equatorial currents, as well as the Easterly Trade Winds, have held a steady and directional influence on the island. Human settlement history, as well as the origins of plants and animals, have largely been tied to the persistent currents. St. Thomas' geographic importance is perhaps best described by deBooy and Faris, who called the island "the place which is on the way to every other place". (1918:54). Because of its strategic location, St. Thomas has often played "the pawn on the chessboard of international politics". (Dookhan, 1976:2).

Due to its historical importance, St. Thomas has often served as the focal point of the West Indies. Being the center of economic activity for much of the past 300 years has allowed changes to occur on the island which have set a pattern for the rest of the Caribbean. The relationship between external economic and political forces and the

land-use of St. Thomas has been a dominant factor throughout history and reasons for settlement, land-use and landscape change are closely tied to such external forces.

St. Thomas was chosen as a study area for several reasons. First, the opportunity to visit and, later, live on the island awoke an interest in understanding how the diverse social and physical environment can hold so many contrasts and conflicts. Second, the lack of readily accessible and current information on the island prompted more detailed research. And, third, the analysis of St. Thomas' cultural and environmental problems seems to provide an insight into the possible future for most of the other Caribbean islands which are just recently experiencing the rapid growth and development of a tourist industry that has shaped and changed the St. Thomas landscape.

Research methodology included personal observations, interviews and archival study. The site was visited and research activities conducted on St. Thomas from June 1980 to January 1981. This thesis provides the synthesis of that fieldwork and an analysis of the data collected.

PART ONE:

A PROBLEM OF WATER

CHAPTER TWO: WATER AVAILABILITY: THE HISTORIC RECORD

> While the island (St. Thomas) is not as well watered as St. John...there are a number of springs on the northern side. An absolute water shortage, such as occasionally experienced on some of the Antillean islands, has not been known to occur here. (deBooy and Faris, 1918:56).

According to deBooy and Faris, St. Thomas in 1917 had such an availability of water so as never to have known a total water shortage. And yet, the problems of water shortage and drought are frequently mentioned in the records of the past sixty years. For example, in 1920, the report read to Congress on the conditions in the Virgin Islands stated: "One of the paramount questions involved in the development of health and happiness of these islands is an adequate water supply...The greatest misfortune of the islands is the lack of water." (SR 160 [66-1:26]).

Again in 1926 it was reported to Congress that "during the drought years, 1920-1924, there was a painful shortage of drinking water, as there are few dependable wells in the islands that contain water fit for human consumption even when boiled." (SD 110 [69-1]).

In 1970, the Soil Survey of the U.S. Virgin Islands noted that:

> "The greatest problem confronting farmers on the islands is that of retaining sufficient soil moisture to produce crops that are otherwise suited to the soil and climate. Drought is more serious now than it ever has been in history. Many springs and wells have gone dry. Subterranean reservoirs have become more and more depleted, even though, according to records, the islands receive about the same amount of rainfall as at any time in the past." (1970:75).

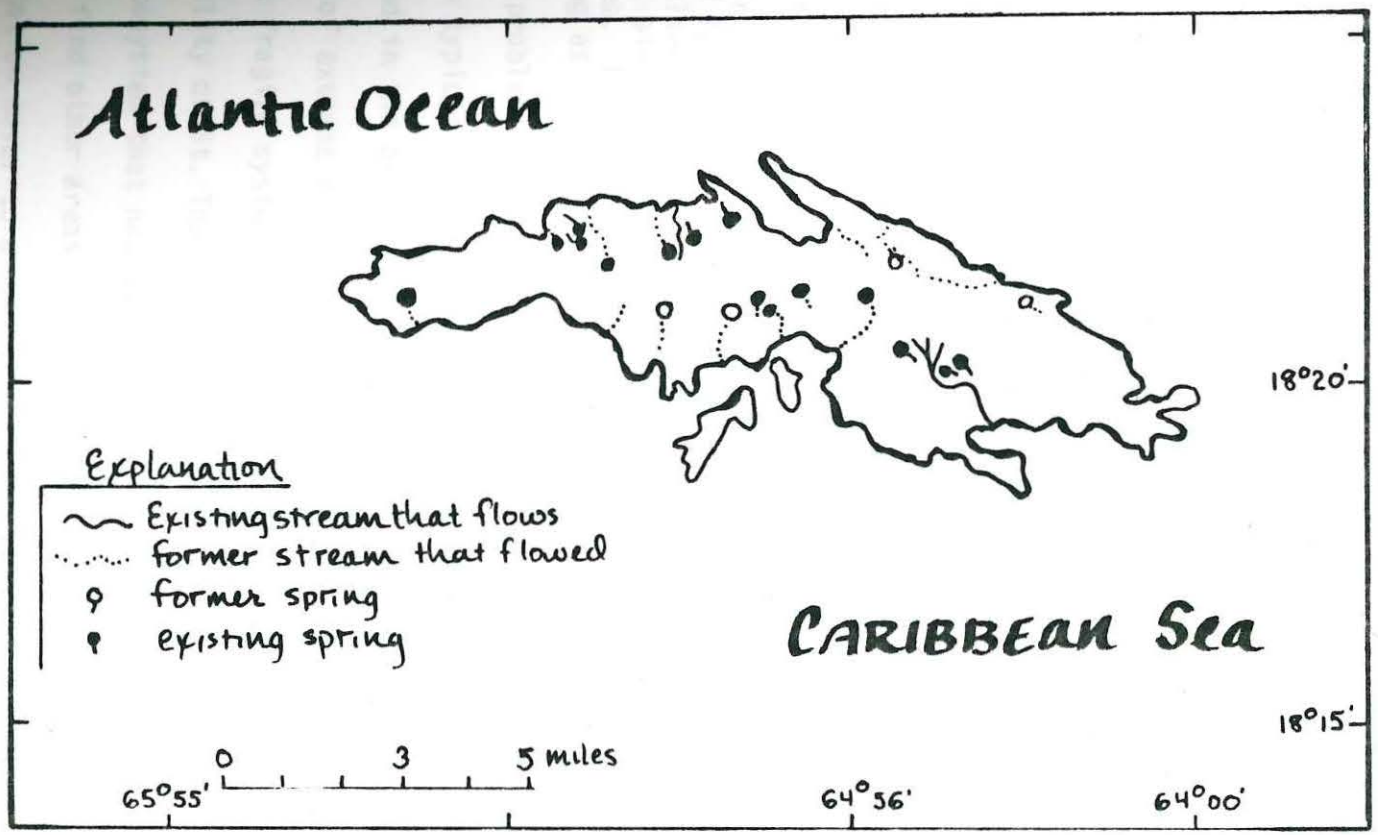
Why, if there is adequate rainfall, have wells and springs gone dry, and streams ceased to run for more than a few days a year? It is evident that a dramatic change in water availability has occurred, and, furthermore, that change has occurred in the years since American possession

of the islands. (See figure 1).

Several different answers to this question of water shortage have appeared in the literature. In a 1920 House Document on conditions in the U.S.Virgin Islands it was noted: "Agriculture has been injured by the cutting of timber. It has lessened the rainfall and the moisture has not been retained." (HD 734 [66-2]). Water shortages in this case are attributed to deforestation. A 1961 report entitled "Climates of the States" mentioned that rainfall in the Virgin Islands, while above 40 inches annually, is insufficient to meet water demands. Water shortages in this report are attributed to a high evaporation rate and rapid run-off from steep slopes. (1961:3). And, according to Jordan (1972: D216), the current decline in water availability is attributed principally to an increase in evapotranspiration rates, due to the reversion from agricultural lands to dense brush and forest.

Before reconciling the sometimes conflicting answers as to the cause of the water shortage, or even documenting the existence of a water shortage, one must first understand the concept of the hydrologic cycle, and the particular variables that affect the cycle on St. Thomas. Water vapor moves through the atmosphere and precipitates into the ecosystem. The moisture flows through the soil, is taken up by vegetation, and is evaporated back into the atmosphere. The fundamental variables that affect this flow of water are the climate and the physical environment. The following chapters describe the physical landscape, climatic conditions, and the process by which water moves through the ecosystem.

figure 1.



Water Resources: St. Thomas, U.S.V.I.

generalized after Jordan & Cosner, 1974.

CHAPTER THREE: THE PHYSICAL LANDSCAPE

A description of the landscape can be approached from two directions: What currently exists, or what the natural state was. These two directions were illustrated by Gordon in his discussion of natural or physical landscape and the cultural landscape.

> "An archaic term anthropurgic (from Greek for man + work), is revived here because it expresses this idea of man as a unique agent of change. Anthropurgic is defined as influenced by the exercise of human power; operated upon by man, as distinguished from physiurgic, i.e., produced in the course of nature without the intervention of man." (Gordon, 1979:5).

A description of the natural landscape of St. Thomas, then, would be the landscape in its climax form without knowing the influence of humans. However, as remarked by Sauer:

> "In very many parts of the world, Old and New, man has been on hand for so long and in such numbers that great deformation has resulted. We can then hardly speak of a natural balance without him, since man has been exerting sustained and selective pressures. Except at the climatic extremes, there can be no such thing as undisturbed or natural vegetation." (Sauer, 1952:18).

The problem of describing the natural landscape of St. Thomas is complex. As typical of most island ecosystems, the factor of physical isolation aided in the development of a unique, diverse ecosystem. And yet, the lack of extreme environmental pressures affecting this tropical island created a fragile system unable to resist ecological disturbances. The accessibility of St. Thomas to seafaring humans introduced a disturbance to the ecosystem that has continued for 3500 years. Bennett has stated: "One may find other areas in the world's islands where man has altered the vegetation cover to a marked and dramatic degree, but no such area exceeds the Caribbean for the total extent of such change. The plant

geography of this region has become as much a reflection of cultural as of biological and physical processes." (Bennett, 1975:260).

Currently there is little evidence on which to base a detailed study of the St. Thomas original natural landscape. (One paleoethnobotanical study has been attempted in this area of the Caribbean, and the results have yet to be published.) If Bennett is correct, the majority of the Caribbean island vegetation was secondary forest growth at the time of historic contact. The lack of paleoethnobotanical and paleoecological studies for the Caribbean necessitates a general approach towards describing the natural landscape in general terms, based upon the climatic, orographic and edaphic features of the island.

3.1: CLIMATE

As in other oceanic ecosystems, the climate plays a key factor in the development and sustaining of life. The subtropical temperatures, the persistent winds carrying ocean-borne water vapor and the resulting precipitation support an equitable maritime environment. The average temperature is approximately 80°, with little fluctuation occurring during the course of the year. Rain falls throughout the year, occurring less frequently in December, January, and February. The mean annual precipitation is approximately 42 inches, though this figure will vary depending upon the elevation and location of the station. The relatively constant environment supports a lush variety of life. Of the 881 native species of plants recorded by Eggers some 215 species were endemic to the Virgin Islands. (Eggers, 1879:13).

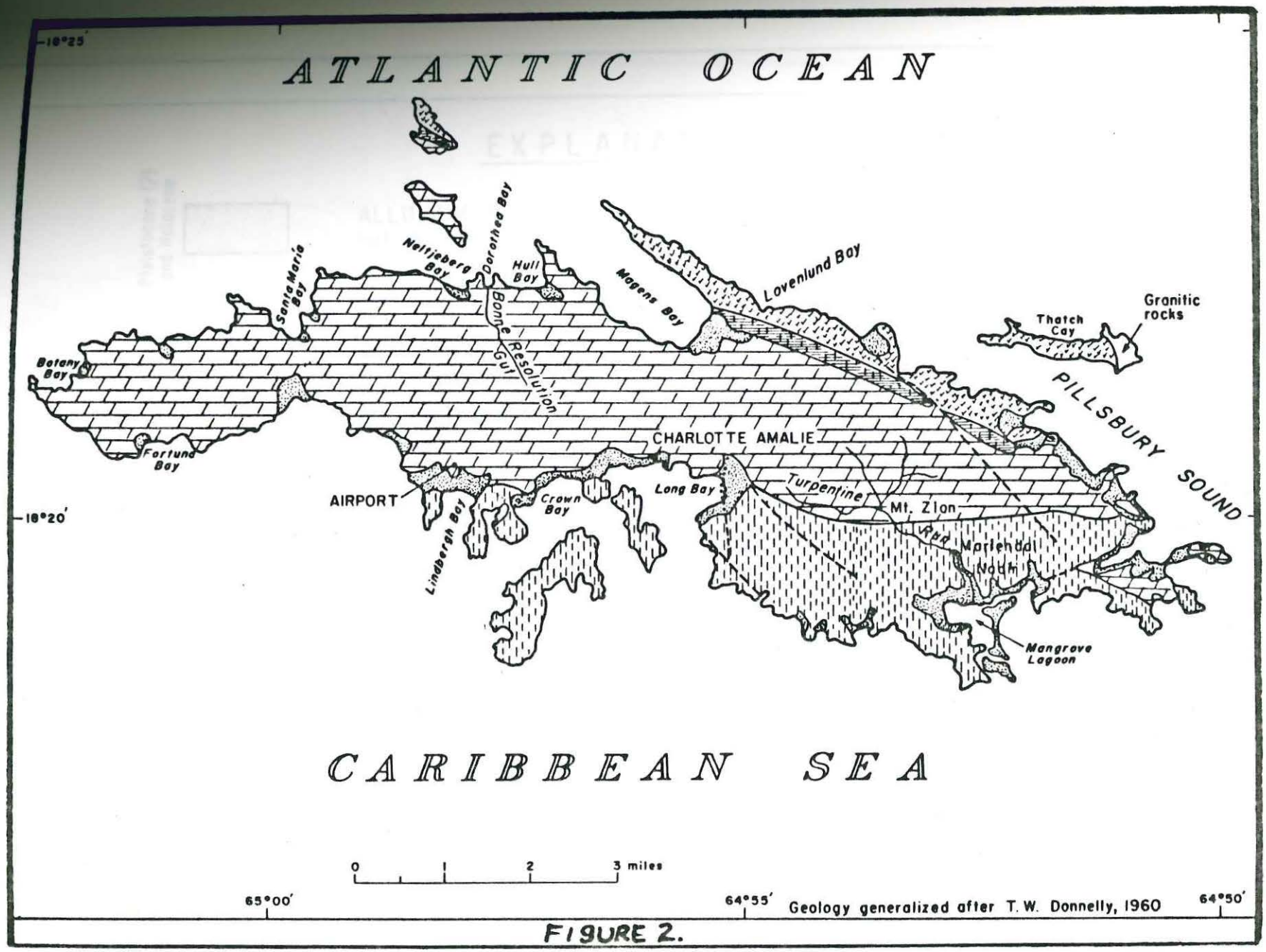
Lacking the extreme seasonal variations found in the temperate zone, relatively minor changes in climatic elements can have a dramatic effect

on the ecosystem. Jackson remarked, "In dry areas, a few years of low rainfall can lead to a deterioration in vegetation which is not always reversed in succeeding years of high rainfall. A decrease in protective vegetation cover in dry years makes an area more susceptible to flooding and erosions when wetter conditions appear, and the deterioration may be accelerated." (Jackson, 1977:48). While St. Thomas is not exactly a "dry area", it is in the subtropical zone, and the ratio of precipitation to potential evapotranspiration indicates it has sub-humid or semi-arid tropical climate. The potential evapotranspiration rate is higher than the mean annual precipitation. Thus the water supply is relatively marginal, and any variability (climatic or otherwise) has great significance.

3.2: TOPOGRAPHY

Born of volcanic activity, it is estimated that the island of St. Thomas has existed for 150 million years. (Donnelly, 1970:1). Basal rocks were deposited and consequently altered by folding, faulting, uplifting, erosion and by the formation of wave-cut terraces. While most of the island is of volcanic origin, a small formation near Magen's Bay is limestone base. The sub-strate is illustrated in figure 2 and explained in figure 3. (See figures 2-3).

Characterized by its high ridge system, St. Thomas rises at the West End from sea level to 1550 feet on Crown Mountain, and 1504 feet on St. Peter Mountain. The East End widens and the ridge fans out to form a sloping upland of less than 1000 feet elevation. Eighty percent of the island is contained in mountainous form with most slopes above twenty percent. (See figure 4). Soil cover is generally thin, particularly on the many slopes approaching 45°, and vegetation plays an important



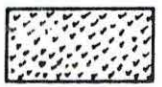
Geology generalized after T. W. Donnelly, 1960

FIGURE 2.

EXPLANATION

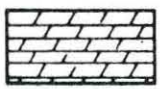
Pleistocene (?) and Holocene

ALLUVIUM - Silt, clay, and thin, discontinuous beds of sand and gravel. Includes beach sand. Estimated maximum thickness 50 ft.

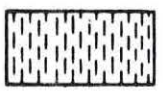


TUTU FORMATION - Tuffaceous conglomeratic mixture derived from older rocks. Contains some limestone, especially near the top. Maximum thickness greater than 6,000 ft.

OUTER BRASS LIMESTONE - Thin-bedded siliceous limestone and a few thin beds of tuff. Estimated maximum thickness 600 ft.



LOUISENHOJ FORMATION - Water-laid tuff, breccia, and a few thin beds of limestone. Maximum thickness known 13,000 ft.



WATER ISLAND FORMATION - Lava flows, flow breccia, and water-laid tuff intruded by dikes and plugs. Maximum thickness greater than 15,000 ft.

Contact

Inferred fault, dotted where concealed

FIGURE 3.

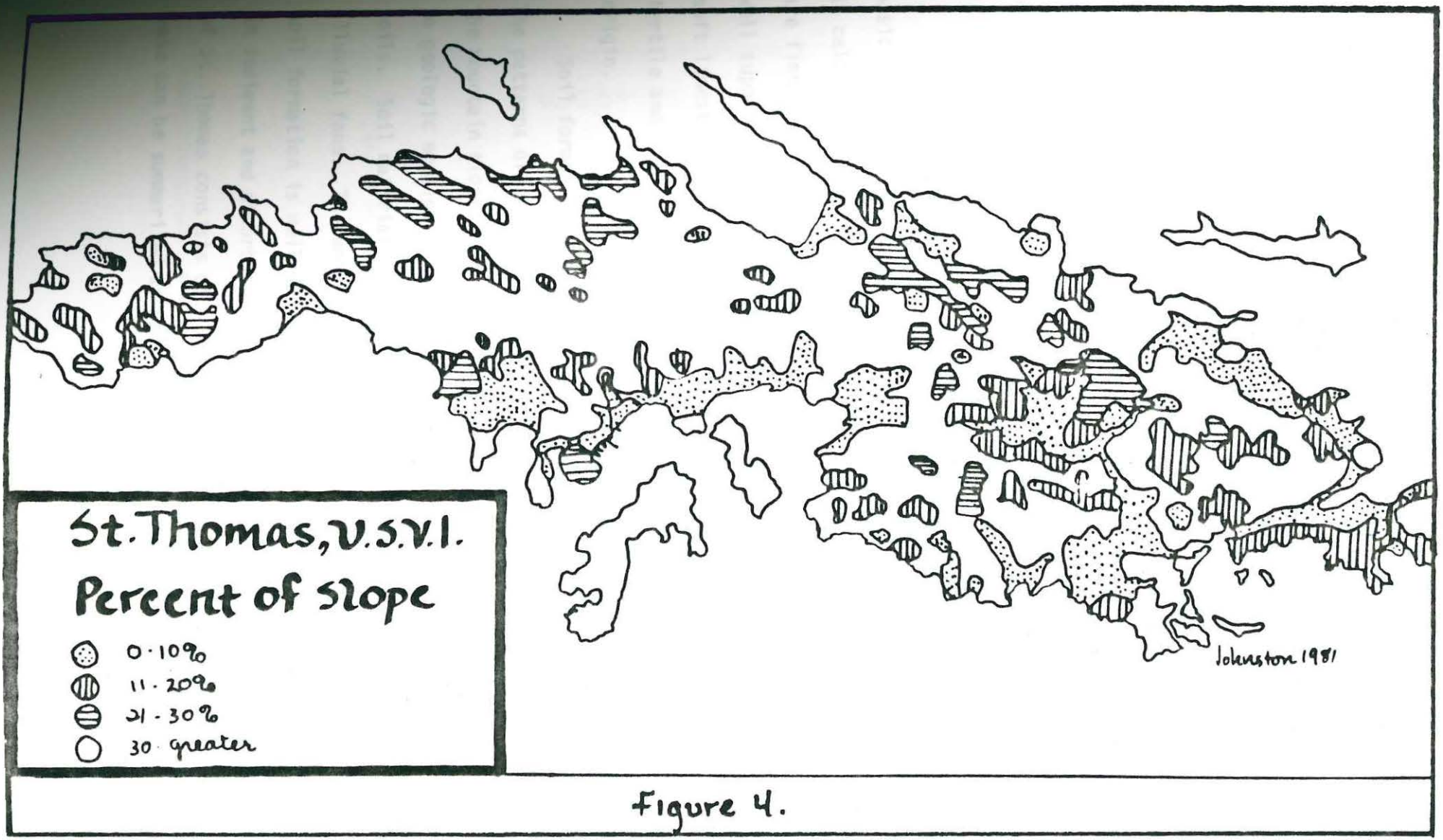

St. Thomas, V.S.V.I.
Percent of slope
0-10%
11-20%
21-30%
30 greater
Johnston 1981

Figure 4.

part in soil stability (Donnelly, 1970:11). An illustration of this relationship between vegetation and soil stability was observed in January of 1981, near Bordeaux Bay. The slope varies from sea level to a 45° angle. Recent development activity resulted in the widening of a dirt access road down the side of the hill. Within weeks after the road cut, the road had eroded down to bedrock with the surrounding vegetation two to four feet higher in elevation. (See figure 5).

3.3: SOILS

Most soils on St. Thomas were formed in material derived from basic volcanic rocks. In general, the base is fine grained and high in calcium, magnesium, sodium, and potassium, and the resulting soils are fine in texture. Commonly clays and clay loams, these soils are well supplied with nutrients. Soils formed in sediments derived from soft limestone are also fine textured clays. They are, however, less fertile and the depth of soil considerably less than those of volcanic origin.

Soil formation is also influenced by the shape of the terrain. The patterns of drainage, erosion, plant cover and soil temperature on the mountain slopes create a relatively impermeable, shallow soil subject to geologic erosion. Thus the soils on the slopes are generally young soils. Soil material moved downslope is deposited on foot slopes and alluvial fans. The erosion pressures are considerably lessened and the soil formation is well-developed. These bottom lands are generally deep in sediment and absorb and store precipitation at a faster rate. As most of St. Thomas consists of steep terrain, the characteristics of its soil base can be summarized as shallow, impermeable or poor draining soils with

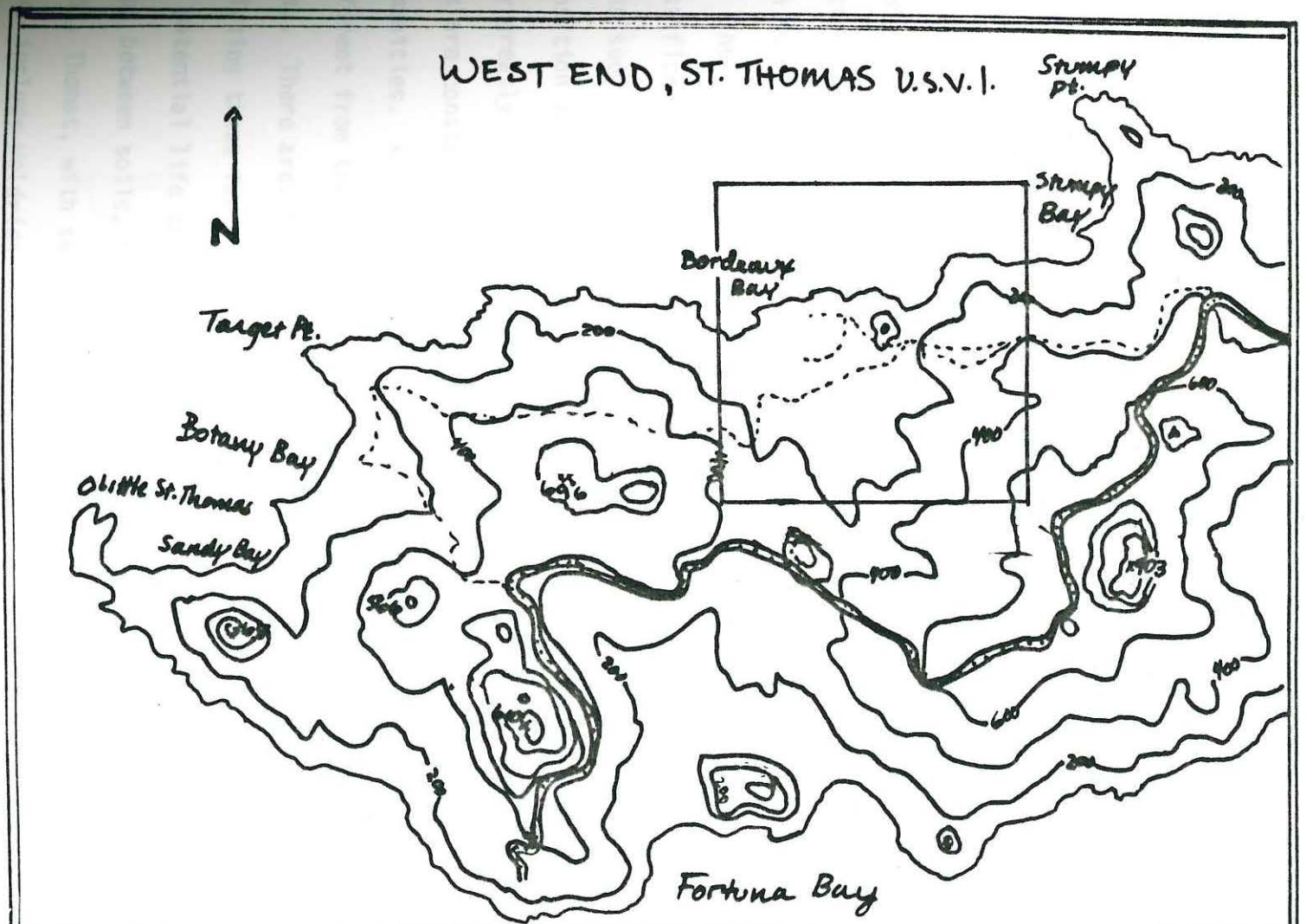


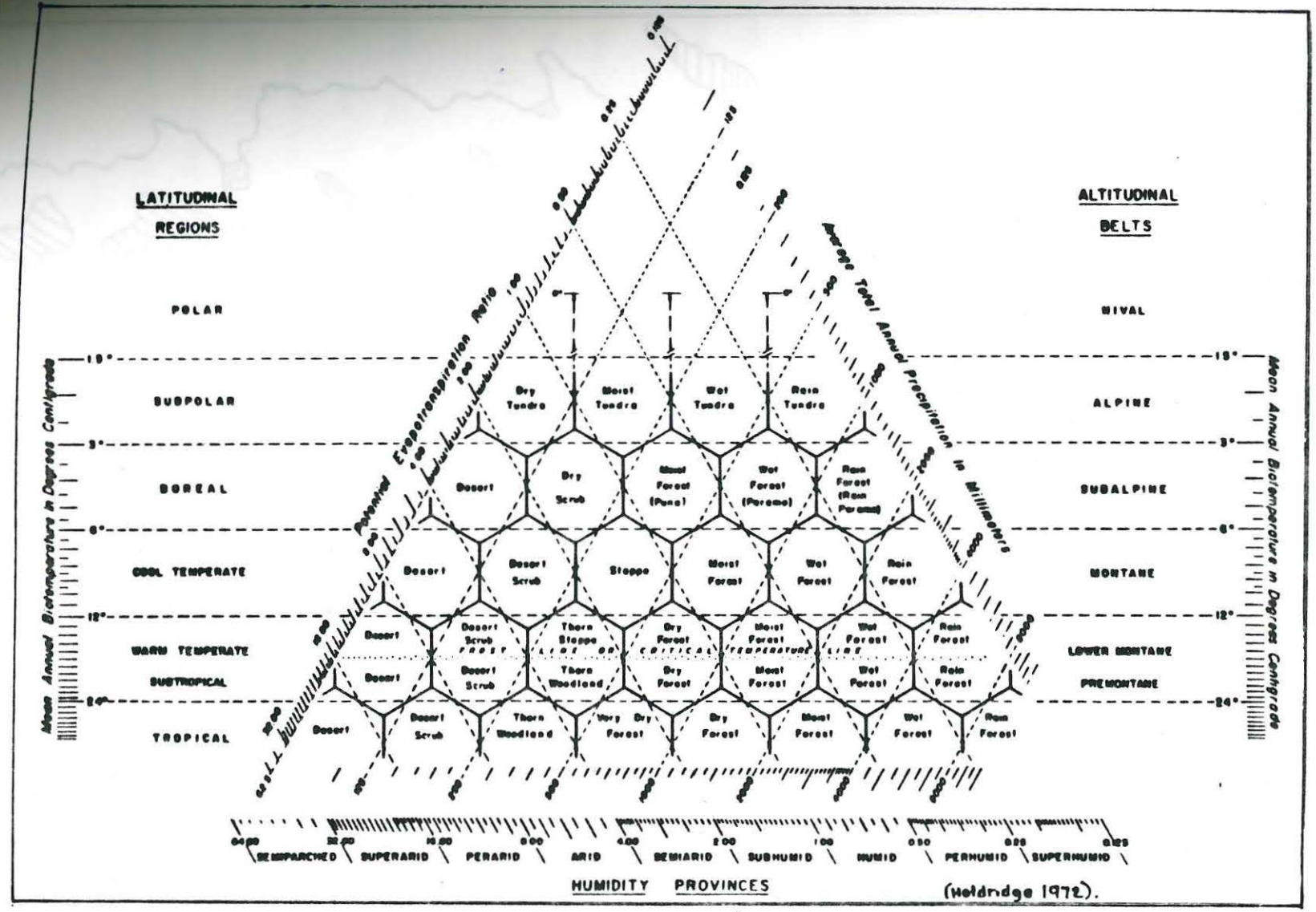
FIGURE 5. BORDEAX BAY LOCATION MAP

little capacity for storing sub-surface water. (Rivera et al, 1970:70).

3.4: LIFE ZONES

Based upon the Holdridge classification system, two life zones are found in St. Thomas: the subtropical dry forest and the subtropical moist forest. (See figure 6). According to Eggers (1879:6) there exist four vegetation zones in the Virgin Islands: littoral, shrubby (croton vegetation), the sylvan (mixed evergreen and deciduous forest), and the region of cultivation. In a terrestrial vegetation map drawn by Zube (1968), there are eight zones: beach, mangrove, croton-acacia, wind flattened scrub, cactus-scrub woodlands, dry forest, moist forest and rain forest. (See figure 7).

The life zone concept is a cultural scheme. While an orderly classification of the ecosystem is necessary for the study, the patterns seen in nature are rarely constrained to distinct boundaries. Transition zones occur between life zones, the characteristics of which vary greatly due to differences in the local environment. As communities are constantly changing, so too are the definitions of those communities. A description of the island in 1500 A.D. might be totally different from the island in 1500 B.C., and different from the island today. There are, however, factors that are relatively constant, and by analyzing these factors a predictive model can be formed illustrating the potential life zones of St. Thomas. By identifying the relationships between soils, topography, and climate, four general zones occur in St. Thomas, with several community types within each zone. These zones include Holdridge's subtropical dry forest and subtropical moist forest zones, as well as the transitional vegetation, occurring between



(Holdridge 1972).

FIGURE 6.

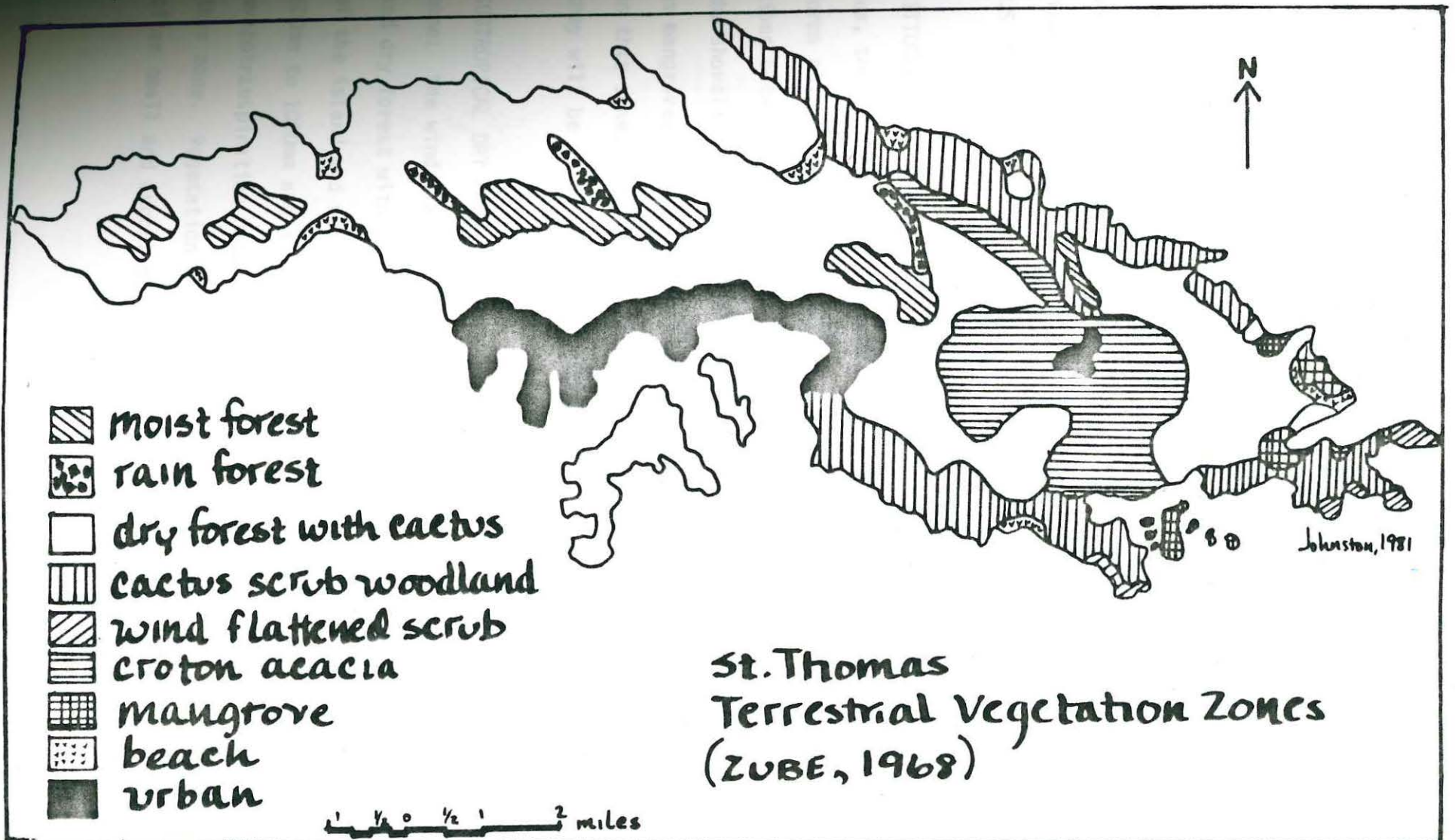

N
moist forest
rain forest
dry forest with cactus
cactus scrub woodland
wind flattened scrub
croton acacia
mangrove
beach
urban
1 ½ 0 ½ 1 2 miles
St. Thomas
Terrestrial Vegetation Zones
(ZUBE, 1968)
Johnston, 1981

FIGURE 7.

moist and wet forest, and known here as the wet forest zone. In addition, the littoral zone is considered. These zones are broadly interpreted onto a map, representing the natural range of communities. Definitions of the formations are taken from Beard's 1944 studies of the natural vegetation of Tobago, British West Indies, and climax vegetation of Tropical America, Ewel and Whitmore's study of the ecozones of Puerto Rico and the U.S. Virgin Islands (1973) and from analysis of coastal zone ecosystems in the U.S. Virgin Islands. (See figure 8).

LITTORAL ZONE: Broadly defined as the transition zone between land and sea, the littoral zone is characterized by many specially adapted life forms able to live under extreme conditions. Habitats include associations between the off shore (coral reefs, sandy sea beds and grass beds), the shoreline (beaches, rocky shores and cliffs), and communities such as mangroves and salt ponds. (See figure 9). Littoral woodlands occur in this zone, but as they are components of the subtropical dry forest, they will be discussed in that section.

SUBTROPICAL DRY FOREST ZONE: There are four major associations in this zone: the wind flattened scrub, cactus-scrub woodland, thorn woodland, and dry forest with cactus. The vegetation is found in the drier parts of the island and near the shore. Mean annual rainfall ranges from 600mm to 1000mm and according to Holdridge, et al (1971), the potential evapotranspiration rate exceeds the amount of precipitation received in this zone. Vegetation tends to form a complete ground cover, leaves are often small and succulent or coriaceous, and species with thorns and

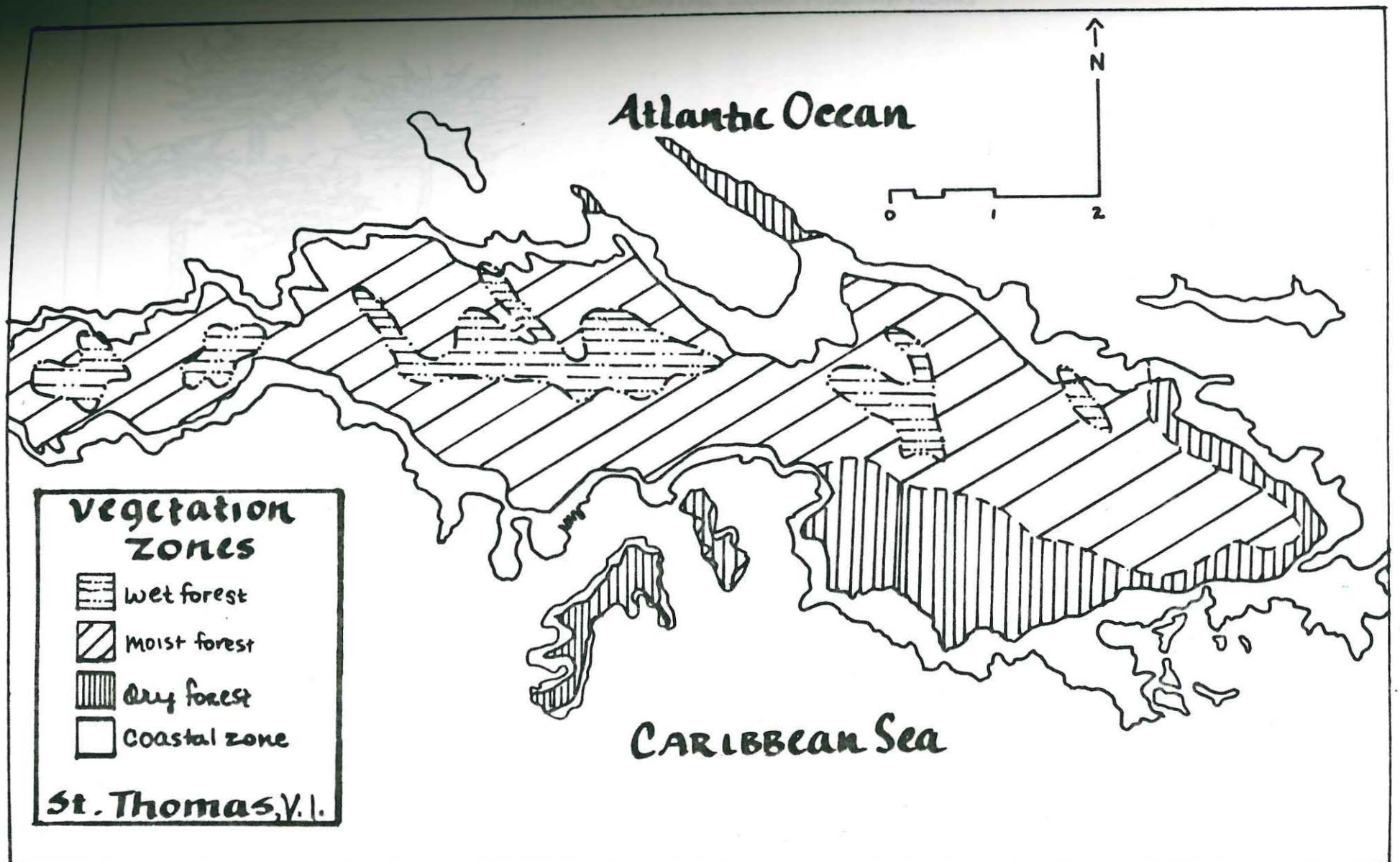

Atlantic Ocean
N
0
1
2
Vegetation Zones
wet forest
moist forest
dry forest
coastal zone
St. Thomas, V.I.
CARIBBEAN Sea

FIGURE 8.

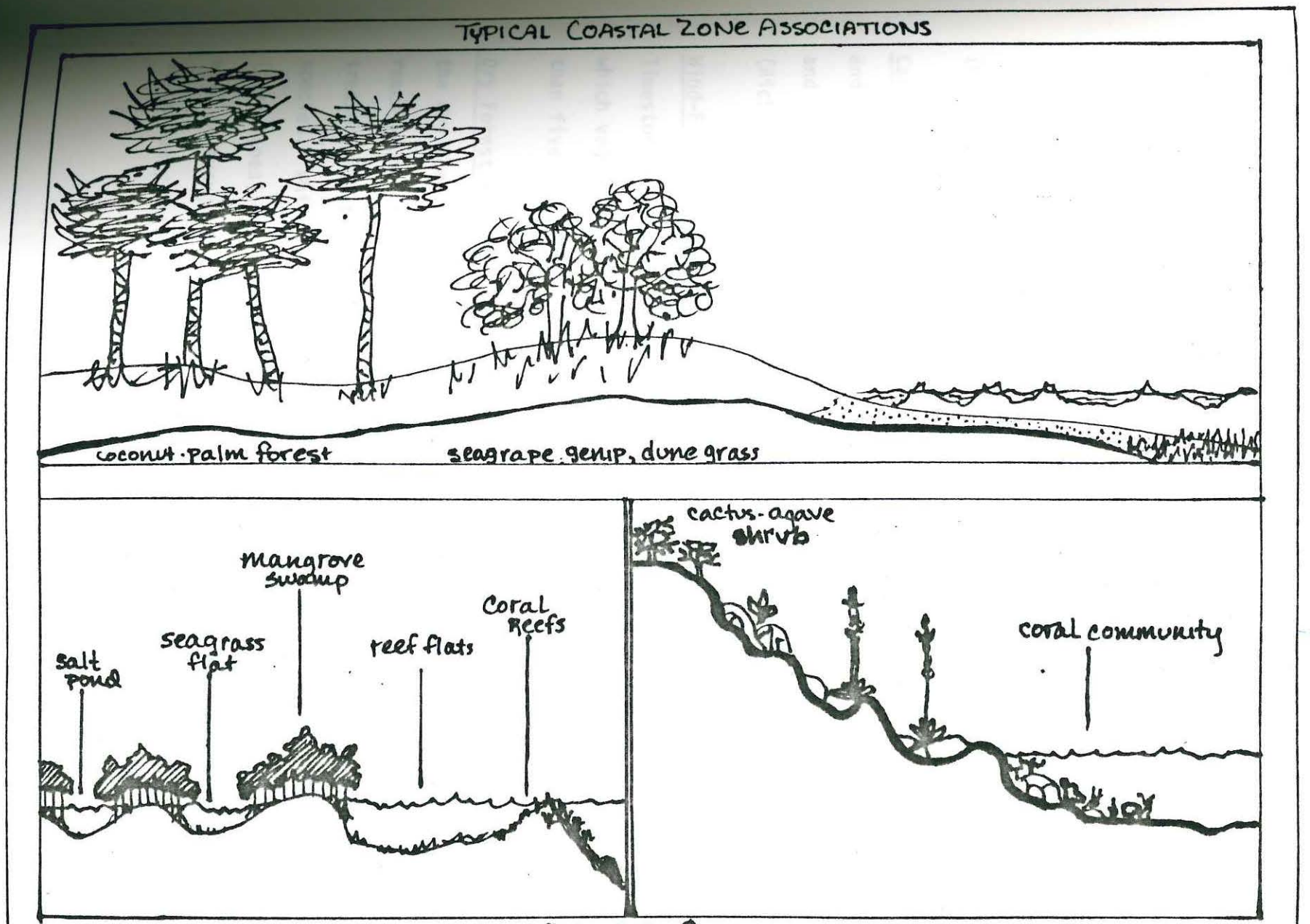

TYPICAL COASTAL ZONE ASSOCIATIONS
coconut · palm forest
seagrape, genip, dune grass
salt pond
seagrass flat
mangrove swamp
reef flats
Coral Reefs
cactus - agave shrub
coral community

FIGURE 9.

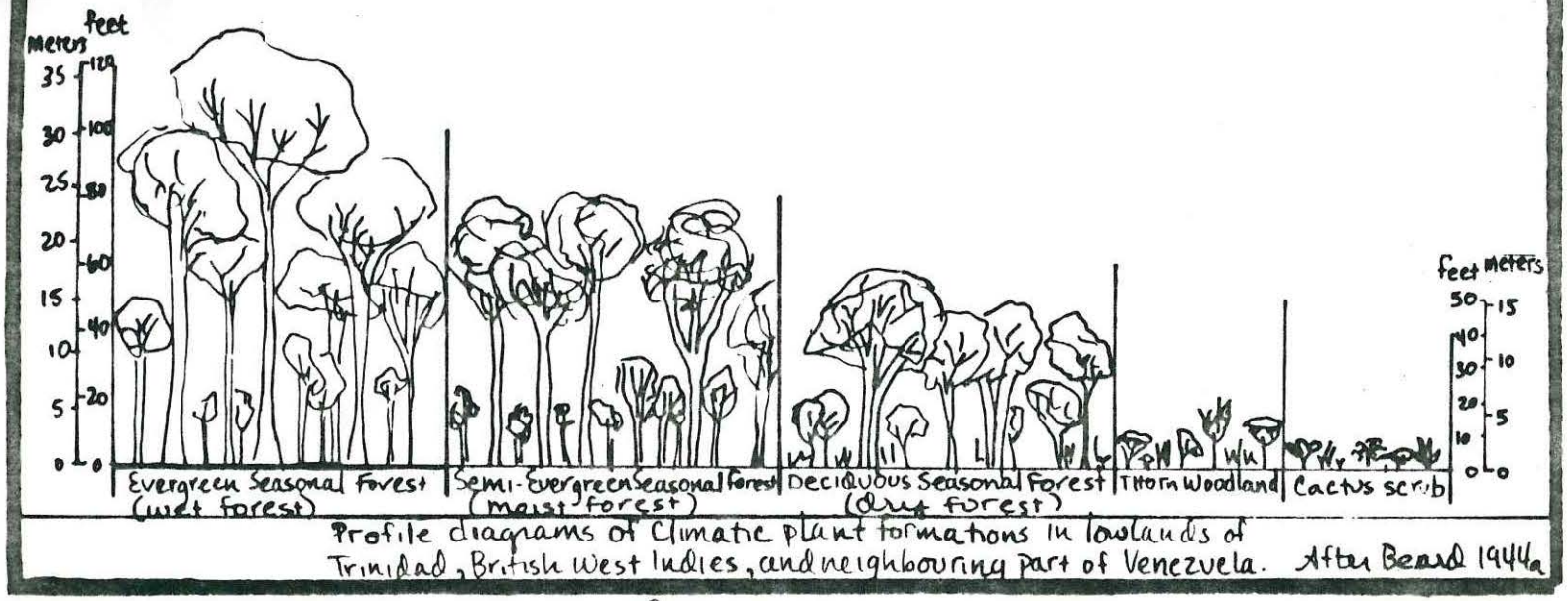
spines are common. (Ewel & Whitmore 1973:15-16).

Thorn Woodland: The thorn woodland is a fairly open scrubby community consisting largely of hard-leaved evergreen trees 3 to 10 meters high, of which most trees are thorny. There is no grass cover, and the only low-growing vegetation consists of a few Bromeliaceae and succulents. (Richards, 1979:321).

Cactus-Scrub Woodland: Open vegetation is dominated by columnar cacti and prickly pears (Opuntia sp.) mingled with scattered thorny bushes and shrubs. There is no grass cover and the ground is often bare. (Richards, 1979:321).

Wind-Flattened Scrub: A strong, salt-laden sea breeze combined with a limestone base produces an extreme edapho-atmospheric association in which vegetation is open. The trees are wind-sculpted, and often less than five meters tall.

Dry Forest With Cactus: Also known as the subtropical deciduous forest, the dry forest cactus is a two storied community in which trees may reach 20 meters. Lianas and epiphytes are rare. Trees are not buttressed, stilt roots are absent, but there are a few important armed species. While palms are not usually represented, small fan-palms (palmettoes) are sometimes abundant. It is largely deciduous forest with an evergreen understory. Ground vegetation is scarce, and the soil is commonly bare. (Beard 1944:140). (See figures 10 and 11).



Profile diagrams of Climatic plant formations in lowlands of Trinidad, British West Indies, and neighbouring part of Venezuela. After Beard 1944a

FIGURE 10

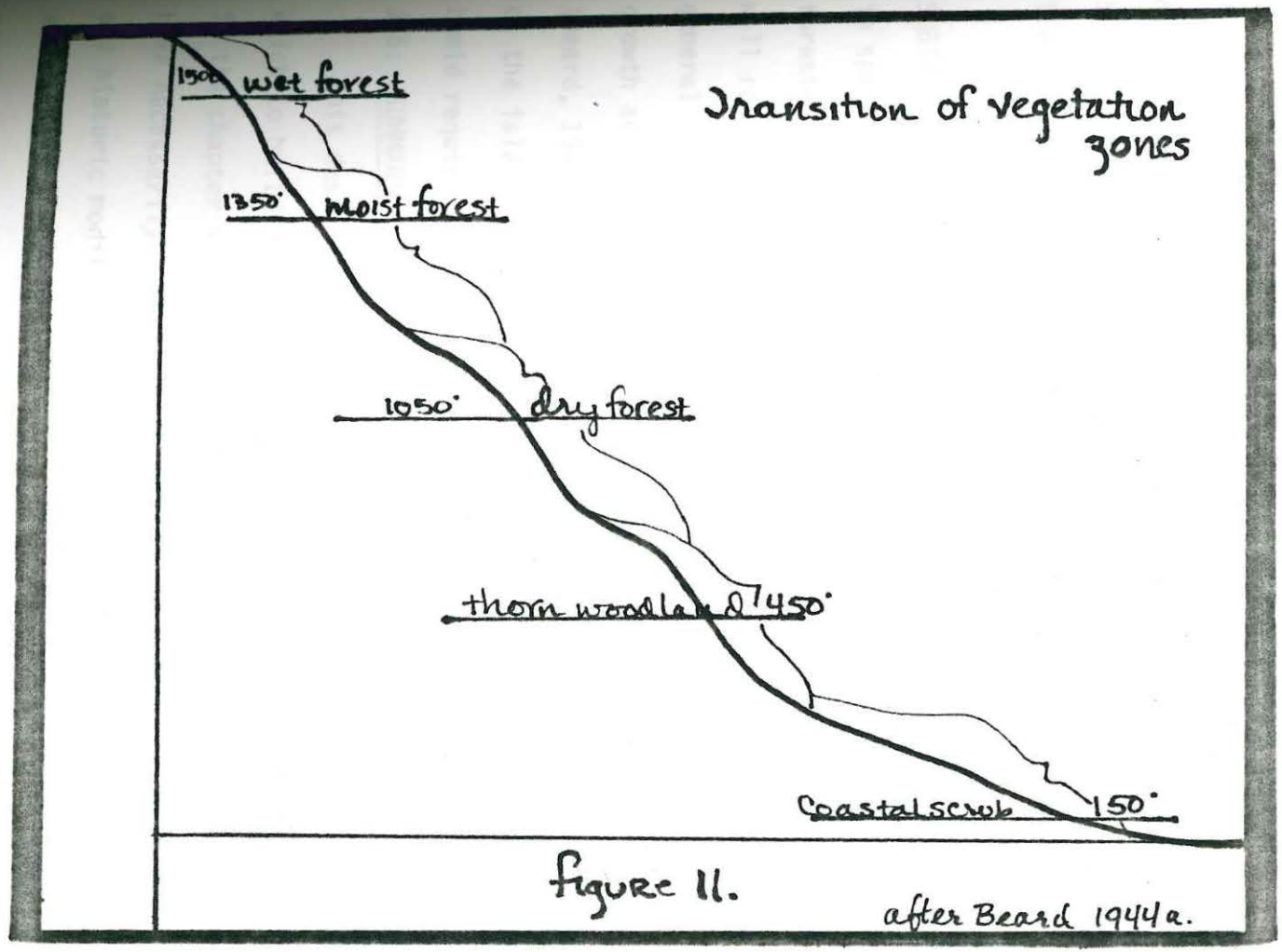


figure 11.

after Beard 1944a.

SUBTROPICAL MOIST FOREST ZONE: In this mixed evergreen-deciduous forest, annual rainfall varies between 1000 or 1100mm to 2000 or 2200mm. Trees grow to a height of 20 meters, and epiphytes are common. This zone is found along the ridge tops and north side of the island, as well as along the banks of intermittent streams. Mangrove swamps occurring in this high rainfall zone are taller than those occurring in drier areas. (Ewel and Whitmore, 1973:27, 29).

SUBTROPICAL WET FOREST ZONE: Vegetation in this zone is relatively rich in species, with epiphytic ferns, bromeliads and orchids common. The forests are evergreen and consist of three stories, the highest of which will reach 30 meters. Individual trees may reach large sizes, but "the general impression is of an occasional huge tree in the midst of smaller growth and the closely ranked columnar effect of rain forest is lacking." (Beard, 1944:138). This vegetation zone is found in only a few places on the island, where precipitation and fog drip provide the necessary humid requirements.

3.5: SUMMARY

This description of the physical landscape has provided a base upon which to build the following chapter on the hydrologic cycle. As stated in the chapter introduction, this treatment of the natural landscape has been necessarily general. The island ecosystem is constantly changing, and historic modification of the landscape has served to create an environment almost totally alien from its prehistoric state. This is particularly evident when looking at Zube's Terrestrial Vegetation Map. (See figure 7). Drawn in 1968 and based upon the existing surface cover

much of the island is portrayed as being in the dry forest with cactus zone. In figure 8, a representation of prehistoric vegetation zones is presented, based upon rainfall distribution, soil, topography and historic accounts. In this map much of the island is shown to be covered by moist forest.

What has caused this change to more xeromorphic vegetation? How is this change related to changes in the hydrologic cycle? The following chapter explores the concept of the hydrologic cycle, addresses the questions of climatic and vegetation change, determines the relationship between landscape and hydrologic change and suggests the reasons for that change.

CHAPTER FOUR: THE HYDROLOGIC CYCLE

Isolated from the mainland by 1000 miles of ocean, St. Thomas is virtually dependent upon rain as its fresh water source. Water vapor formed over the oceans is transported by the trade winds almost year round. When the clouds hit the land mass, the lowering of temperature causes precipitation. The steep terrain of the island encourages a rapid run-off rate, though the amount of run-off on slopes will vary according to surface cover. Water that is absorbed into the soil becomes soil moisture, and is taken up (transpired) into plants, evaporated by the heat of the sun, or percolated down to become part of the subsurface water table. When the soil is saturated and the water table full, run-off occurs, returning water to the sea, where it is taken in vaporous form. This flow of water is known as the hydrologic cycle. (See figure 12).

One way of illustrating the hydrologic cycle is by utilizing the water budget formula in which the amount of precipitation entering into the system is equal to the amount of water leaving the system: precipitation = groundwater + run-off + transpiration + evaporation. The factors that determine the amount of water withheld in the soil, transpired into the vegetation, evaporated from the plants and soil, and run-off into stream flows are complex. Soil type, depth of soil, the parent bedrock, slope, vegetation type, and temperature can all determine or change the proportions in the natural water budget. Thus two areas may receive the same amount of rainfall but, because of differences in one or more of the variables affecting the flow of water, the proportions of the water budget will be different. (See figure 13). The more these variables

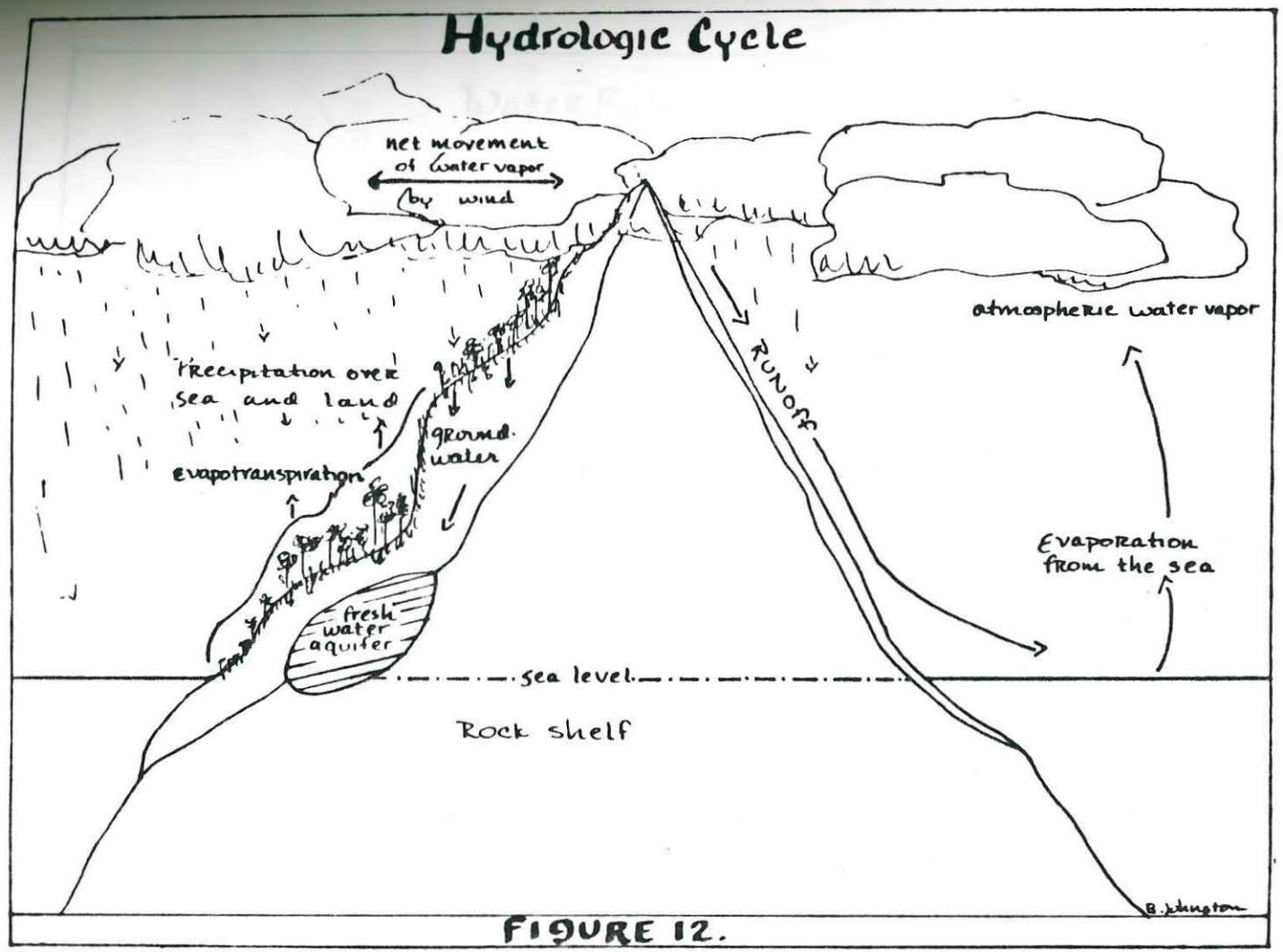

Hydrologic Cycle
net movement of water vapor by wind
atmospheric water vapor
precipitation over sea and land
runoff
ground water
evapotranspiration
Evaporation from the sea
fresh water aquifer
sea level
Rock shelf
B. Johnston

FIGURE 12.

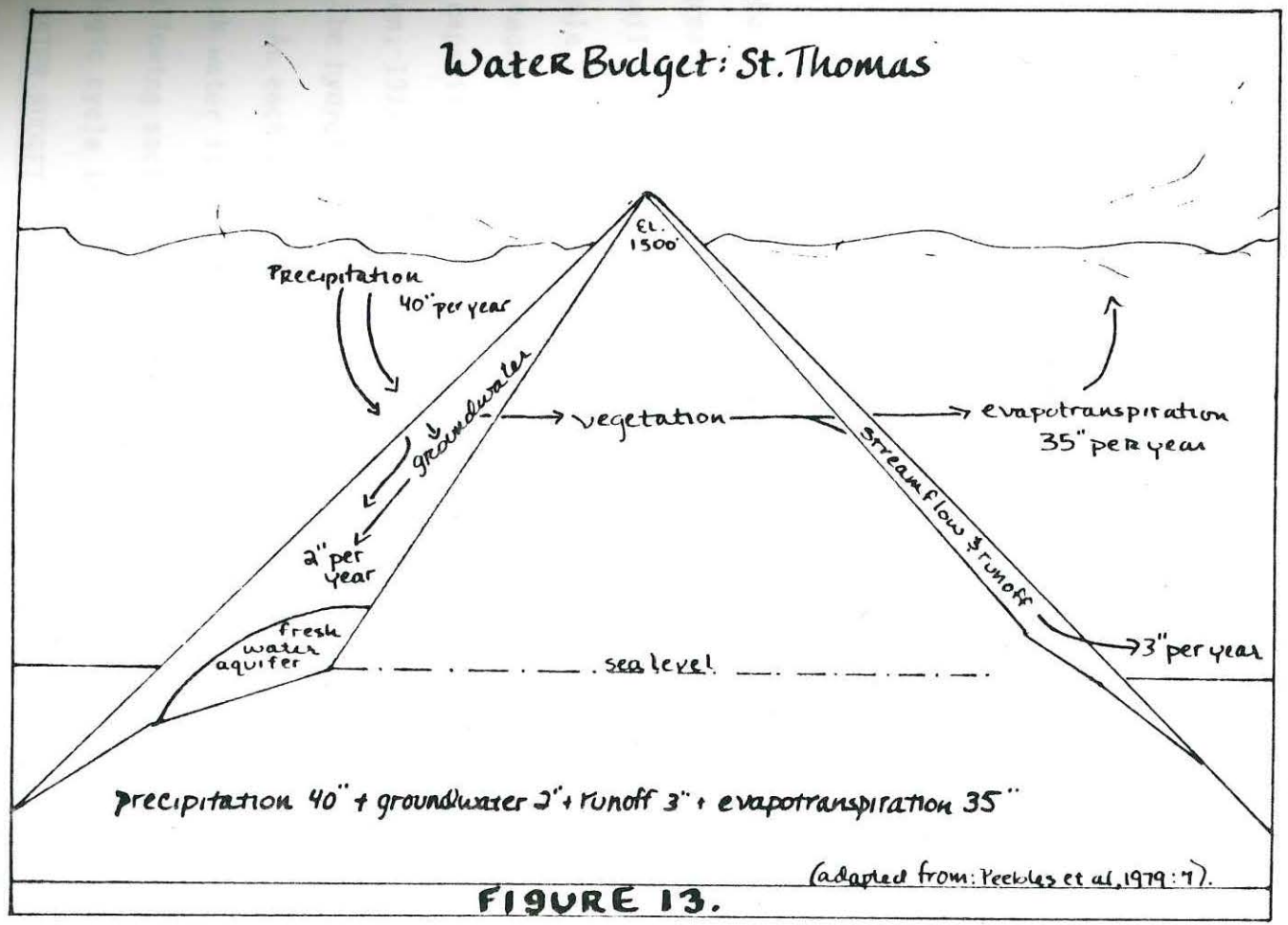

Water Budget: St. Thomas
El. 1500'
Precipitation
40" per year
groundwater
vegetation
evapotranspiration
35" per year
streamflow & runoff
2" per year
fresh water aquifer
sea level
3" per year
precipitation 40" + groundwater 2" + runoff 3" + evapotranspiration 35"
(adapted from: Peebles et al, 1979: 7).

FIGURE 13.

encourage infiltration, the less will be the proportion of rain lost immediately as surface flow. The greater proportion of rain infiltrating will cause a more even, rather than rapid, run-off and streamflow will be prolonged. In the same vein, the more these variables discourage evaporation, the less water will be immediately lost to the atmosphere. Given an adequate supply of water, evaporation in the tropics is high. Potential evapotranspiration remains high throughout the year due to the small variation in solar radiation. Since the greatest loss of water occurs through evapotranspiration, with a constant atmospheric demand, differences in vegetation transpiration rates then play a crucial factor in water loss. Different vegetation types will accordingly have different root depths, and those with the potential to grow to a greater depth will have more water available to use in transpiration. Bare soil or scanty vegetation such as grasses will shortly give up all available soil moisture, but lock in the lower water molecules. A more dense vegetation such as a scrub forest will, due to its greater root depth capability, be able to tap the water below the surface lines. (Jackson, 1977:104).

The hydrologic cycle is a key concept in understanding the flow of water. As each geographic area is unique, so too is the particular way in which water is cycled through the local enviornment. Presented in the following section are the specific variables that influence the hydrologic cycle in St. Thomas.

4.1: WATER BUDGET

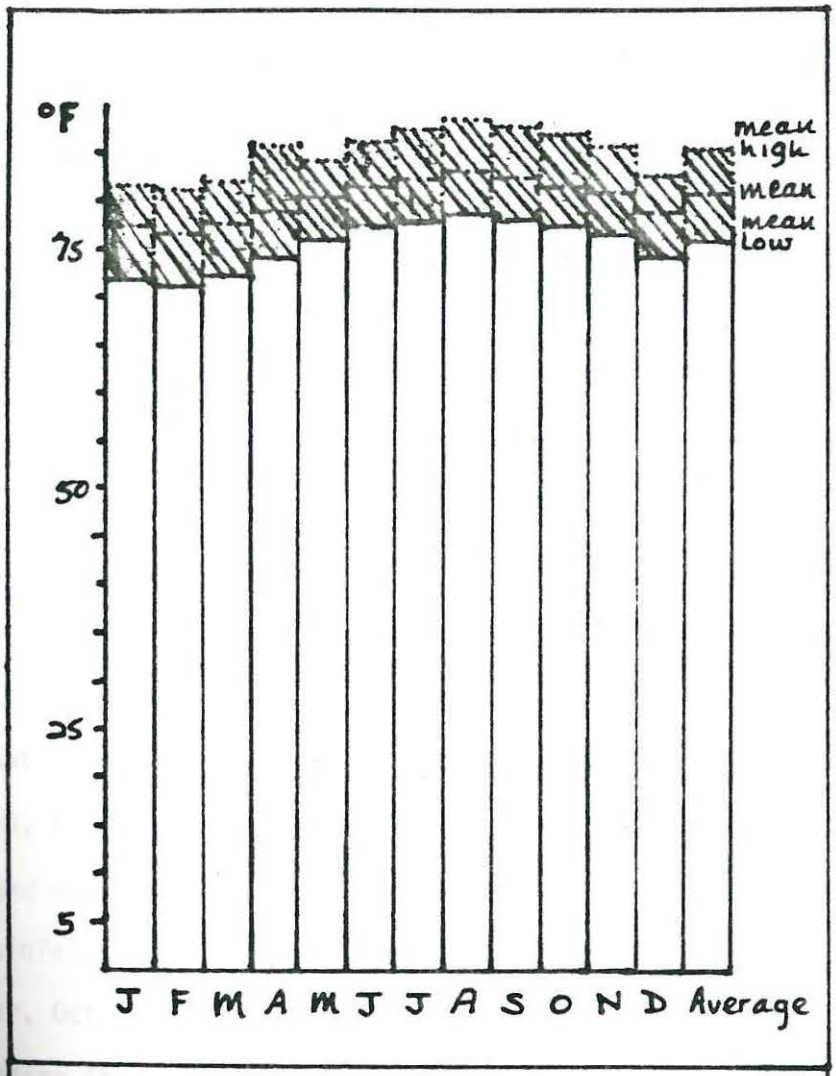
In St. Thomas the average annual rainfall is 44 inches. The average annual temperature is 80°f, and the annual potential evapotranspiration rate is 62 inches. These figures, in combination with topographic features

provide the parameters for the water budget. (See figure 13). It is seen that the greatest amount of water loss is due to evapotranspiration. Consequently, changes in the ability of the vegetation to transpire will affect the amount of water retained in the soil. The flow of a stream during the dry season depends upon, in large part, the availability of moisture in the soil. Thus a change in the amount of rainfall entering the island system, or a change in the amount leaving through evapotranspiration, will stimulate a change in stream flow patterns.

4.2: CLIMATE

As previously mentioned, the average temperature of St. Thomas is 80°f. The fluctuation of temperature through the year is minor, 15.8°f, and the average daily fluctuation is 15°f. (See figure 14). Can a correlation be found between temperature changes and a decrease in water availability? Increased temperatures will cause additional water stress on plants and a potential deterioration of the vegetation as well as a decrease in soil moisture due to direct evaporation. By looking at the climategraphs presented in figure 19, the average daily temperature for 1833, 1917-1941, 1930-1940, and 1931-1955 is seen to have changed very little. It is concluded that changes in the surface cover and evapotranspiration rates cannot be attributed to changes in atmospheric temperatures.

An additional factor where temperature is crucial is in the formation of hurricanes. Tropical cyclones, or hurricanes, are formed over water having a temperature of at least 82°f (27°c). Characterized by high winds and heavy rainfalls, the intensity of the storm is of major importance. The effects of hurricanes can include tidal waves, flooding, and deforestation through winds, and the impacts to vegetation are often



Mean Monthly Air Temperature
Charlotte Amalie 1922-1960

figure 14.

dramatic. The character of the vegetation is commonly changed, and the contribution of rainfall to the average annual levels is significant. Figure 20 gives a running mean for rainfall at Barrack's station in St. Thomas. Years in which hurricanes passed directly overhead include 1916, 1924 and 1933. These are all years in which rainfall was significantly higher than the average annual rainfall. While a seasonal pattern of hurricane occurrence can be determined, there is little pattern to the yearly occurrences in the St. Thomas area. (See figure 15). It is suggested that a major temperature change resulting in the extension of the hot season would result in a longer hurricane season, and therefore a higher probability of hurricane occurrence in the immediate area. As illustrated in figure 14, no such change has occurred in recent years.

Another important climatic factor in St. Thomas is the circulation of winds. The steadiness of the tradewinds are a noted feature in the Lesser Antilles. Almost without exception they blow from an easterly direction, between North-northeast and South-southeast, and provide a year round source of moisture in the form of rain. (Smedley, 1962:5).

Rainfall is seasonal, with the rainy season occurring during August, September, October and November, and again in May. Nearly half the rain falls during the August-November period. (See figure 16). Rains generally occur in the form of short, intense showers lasting for a few minutes. While the records of rainfall date back to earlier colonial times, there are many discrepancies and breaks in the record.

Depending upon where the rainfall is measured, the annual total can vary as much as 20 inches. The distribution of rainfall is illustrated in figure 17. Topographic features and the direction of the prevailing winds can provide a significant difference in the average annual figures.

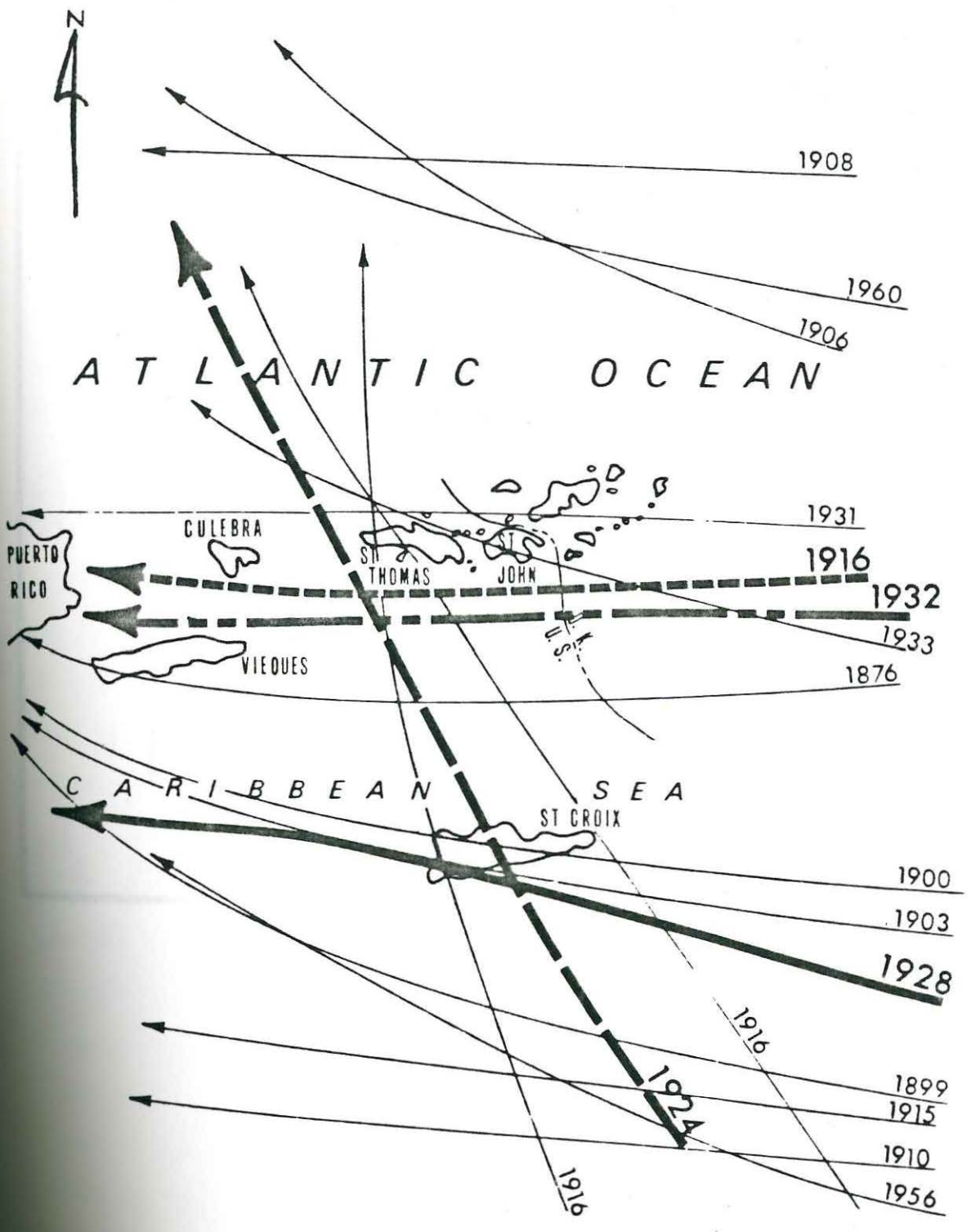
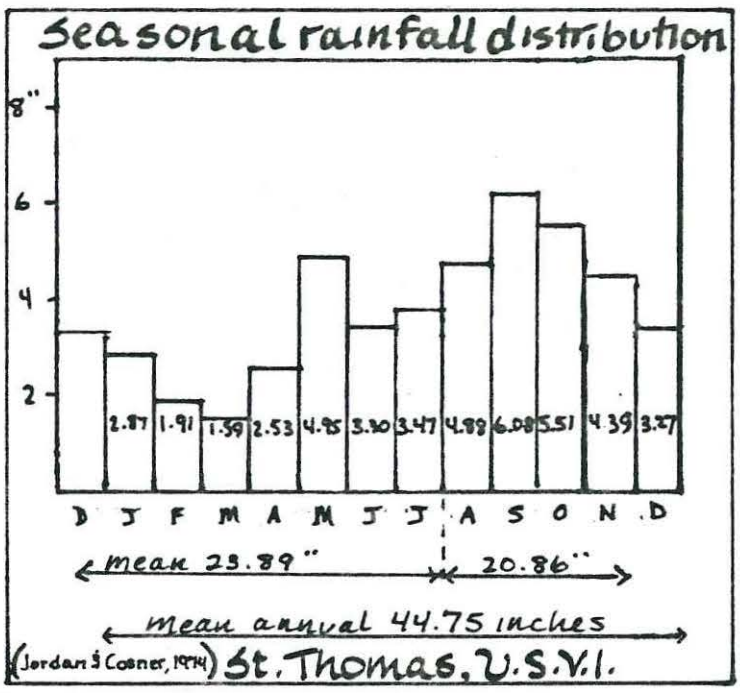


Figure 15. Hurricane paths that have affected the Virgin Islands since 1876. From U.S. Army, 1975.

FIGURE 16.


Seasonal rainfall distribution
8"
6
4
2
2.87
1.91
1.59
2.53
4.85
3.30
3.47
4.88
6.08
5.51
4.39
3.27
D J F M A M J J A S O N D
mean 23.89"
20.86"
mean annual 44.75 inches
(Jordan & Cosner, 1974) St. Thomas, U.S.V.I.

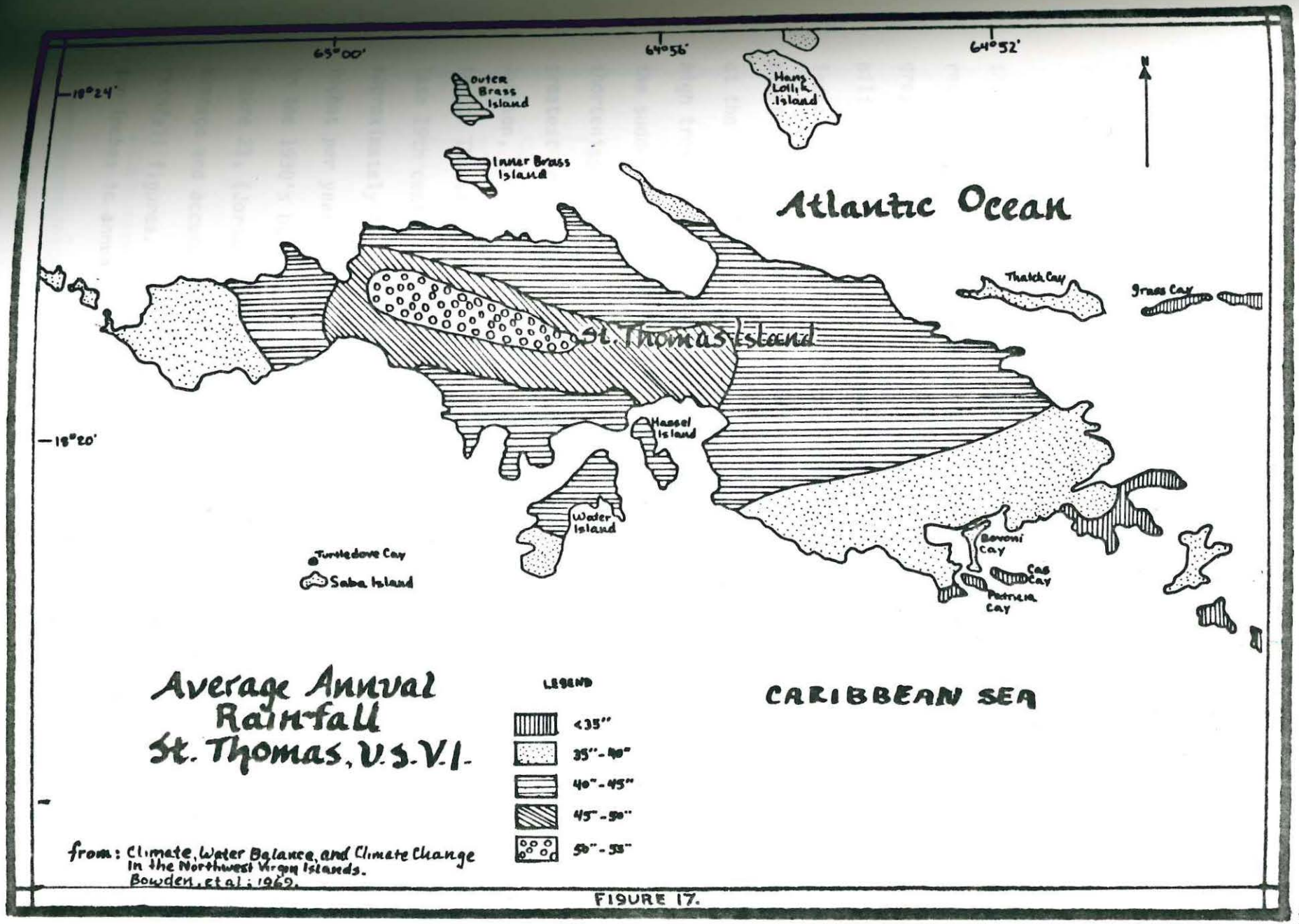
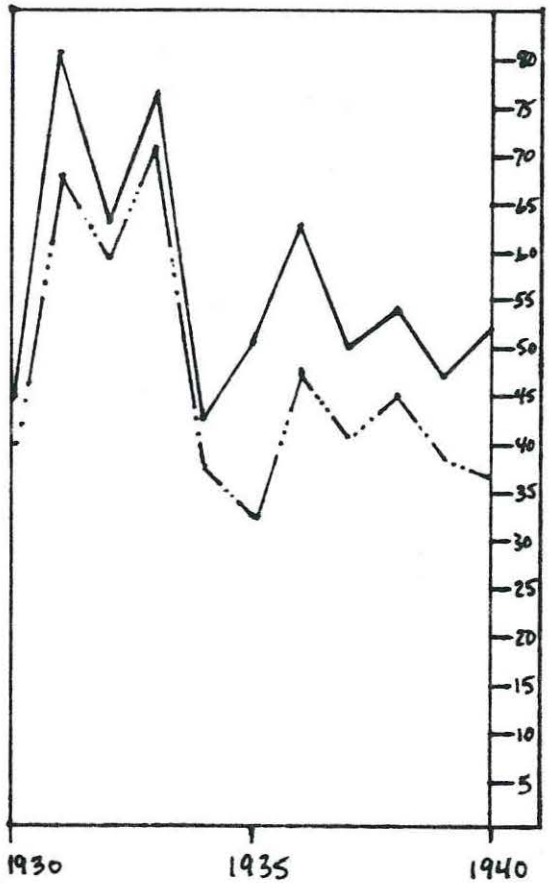

65°00'
64°56'
64°52'
18°24'
18°20'
N
Outer Brass Island
Hans Lollik Island
Inner Brass Island
Atlantic Ocean
Thatch Cay
Grass Cay
St. Thomas Island
Hassel Island
Water Island
Turtledove Cay
Saba Island
Bovoni Cay
Cas Cay
Patricia Cay
Average Annual Rainfall St. Thomas, U.S.V.I.
LEGEND
<35"
35"-40"
40"-45"
45"-50"
50"-55"
CARIBBEAN SEA
from: Climate, Water Balance, and Climate Change in the Northwest Virgin Islands. Bowden, et al; 1969.

FIGURE 17.

This difference is illustrated in figure 18. Average annual rainfall figures for two stations are plotted for a ten year period and show an average ten-inch difference in rainfall. Barracks Station is at sea level near town, Bonme Esperance is at an elevation of 675 feet.

The question of climatic change is a crucial element in determining the reasons why the hydrologic balance in St. Thomas has changed. The records of rainfall and temperature are illustrated in a series of climate graphs (see figure 19) and indicate a period of increasing water availability occurring towards the end of the 19th century. Kraus (1955) has indicated that rainfall was above the 1881-1940 world average in the nineteenth century in the tropics, but that there was an abrupt decrease at the turn of the century. He suggests that the period of comparatively high tropical rainfall began in the 1820's or earlier, and postulates the sudden decrease resulted from a narrowing of the rain belts and a shortening of the wet season. He also contends that the effects were greatest in the subtropics or at the arid boundaries. (Kraus, 1958 in Jackson, 1977:67). This theory is supported by the evidence of rainfall in St. Thomas, at least to the effect that rainfall was heavier in the late 19th century and has since declined. Rainfall from 1878-1900 averages approximately 48 inches per year. By 1910 the average had dropped to 43 inches per year. (See figure 20). The average annual rainfall increased in the 1930's but then dropped to approximately 40 inches in the 1960's. Figure 21, (Jordan and Cosner, 1974:7), illustrates the ten year running average and accumulated departure from the average based upon the annual rainfall figures. Jordan and Cosner note a long term decline of about ten inches in annual rainfall had occurred since the peak surplus in the



annual rainfall from two stations on St. Thomas, U.S.V.I.

Barracks Station
elevation 10' average annual rainfall : 45.77"

Bonne Esperance Station
elevation 675' average annual rainfall : 55.31"

average difference in annual rainfall ~ 9.54"
extreme minimum difference in rainfall ~ 5.2"
extreme maximum difference in rainfall ~ 16.21"

(data from: Stone, 1941:26).

FIGURE 18.

FIGURE 19.

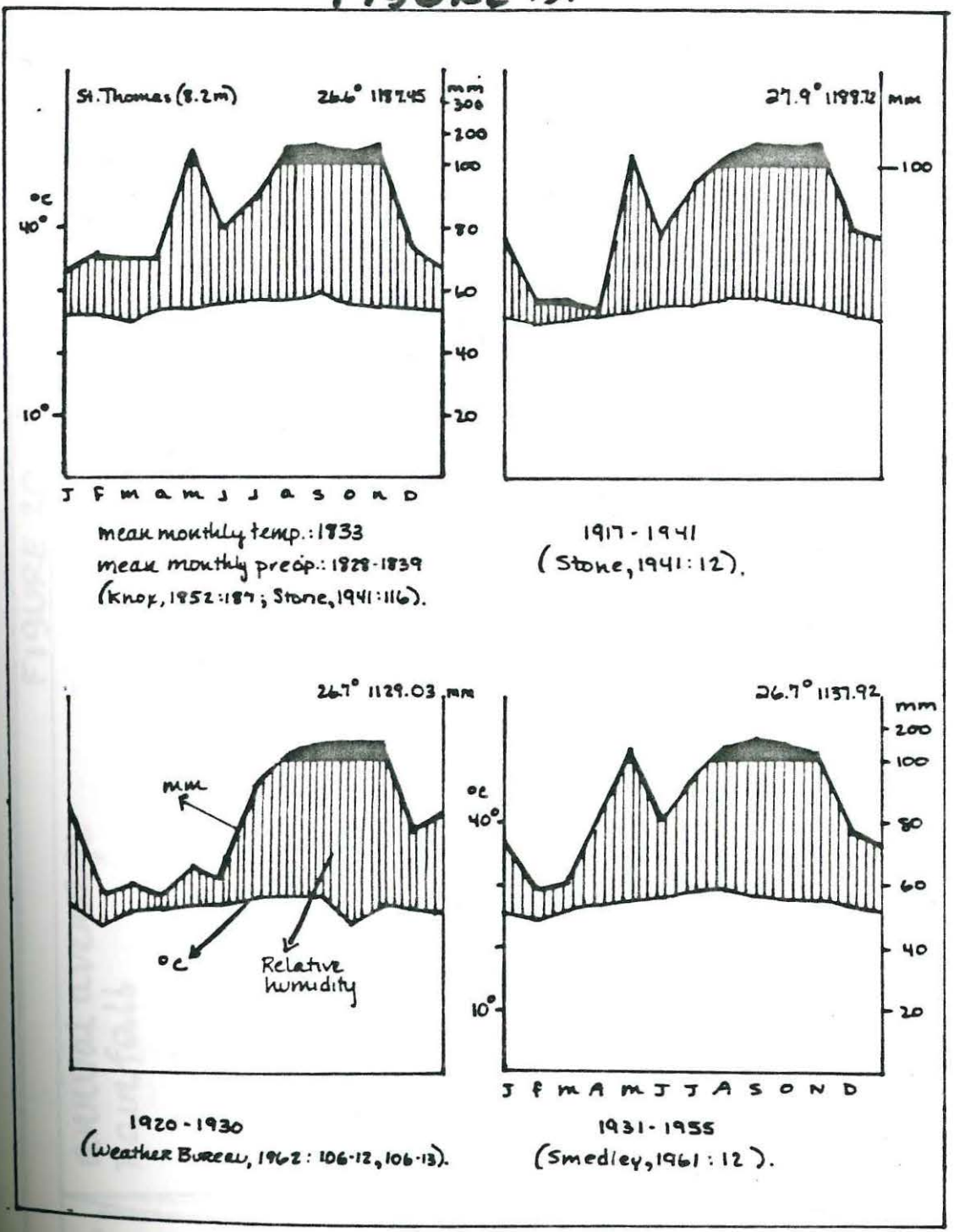
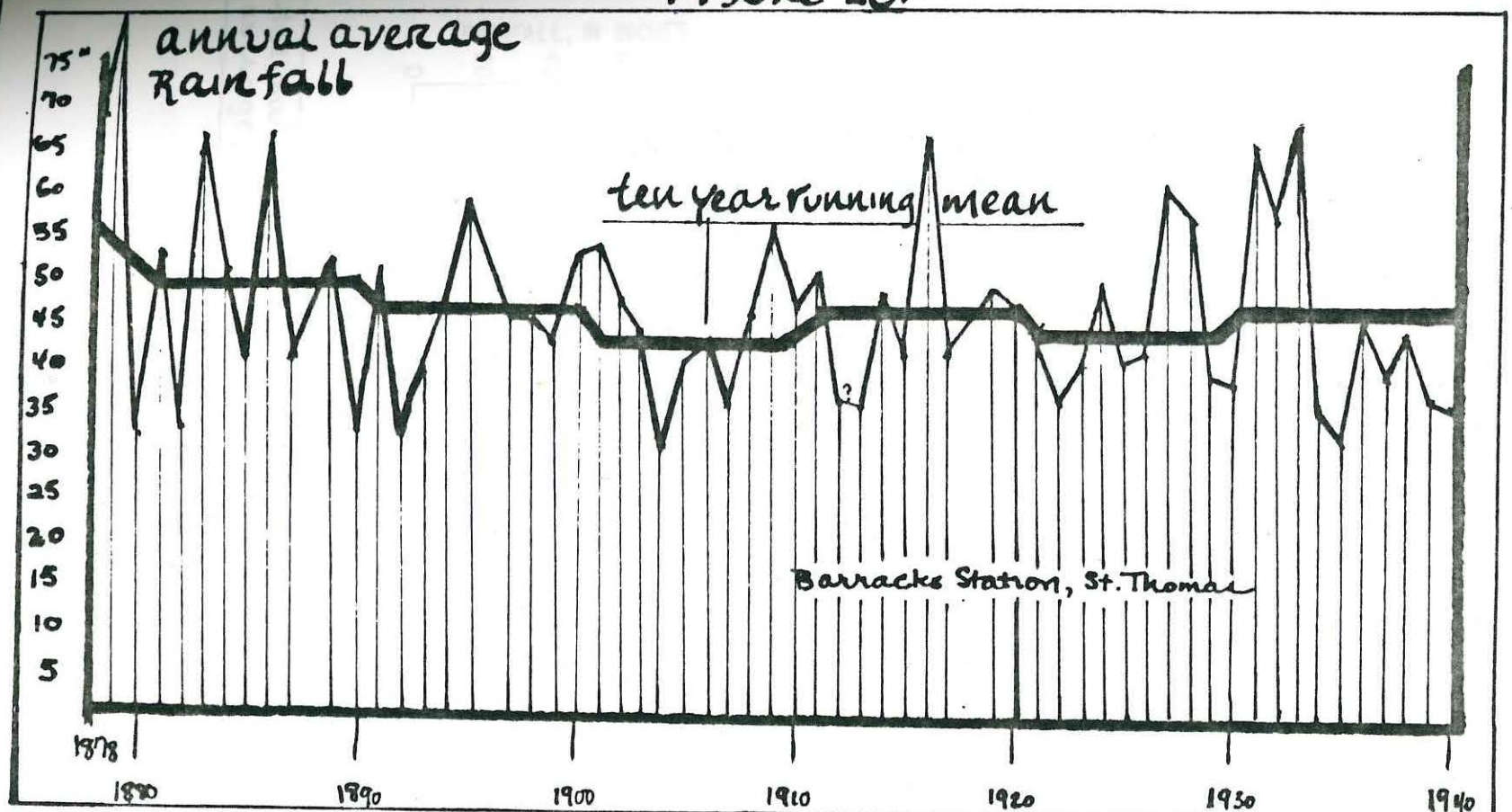
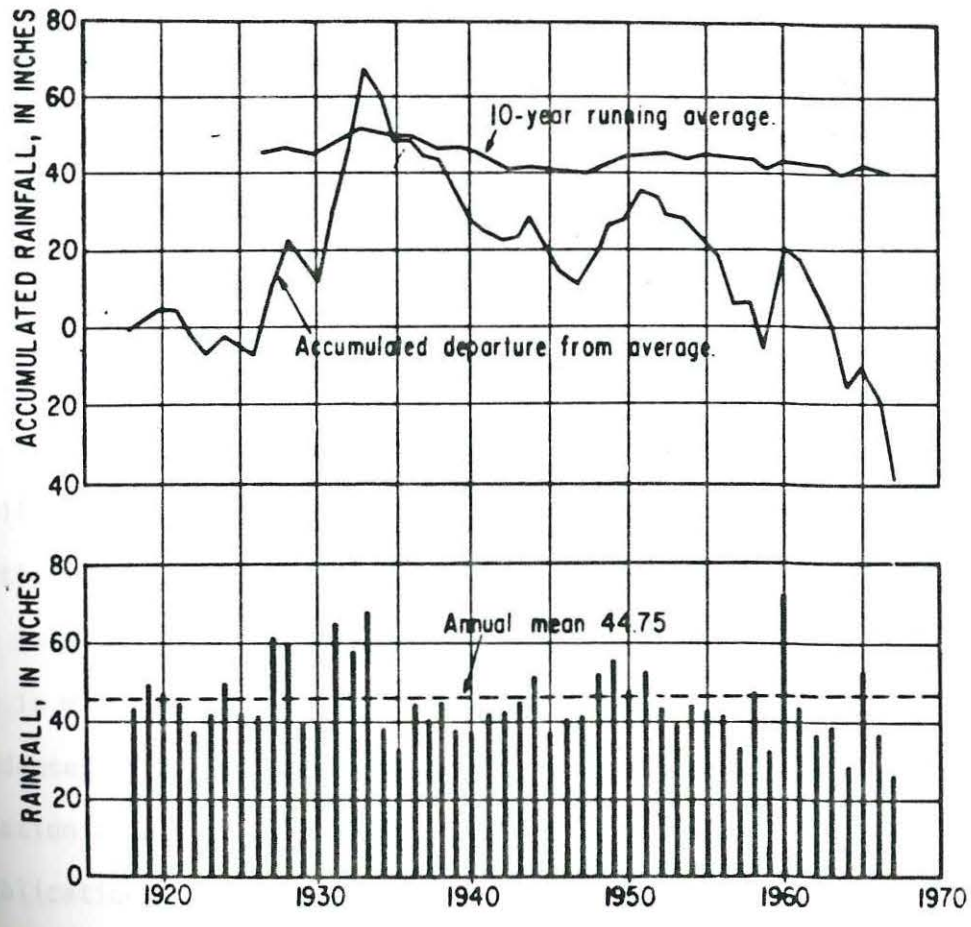

St. Thomas (8.2m)
26.6° 1187.45
mm
300
200
100
80
60
40
20
°C
40°
10°
J F M A M J J A S O N D
mean monthly temp.: 1833
mean monthly precip.: 1828-1839
(Knox, 1852:187; Stone, 1941:116).
27.9° 1198.12
mm
100
1917-1941
(Stone, 1941:12).
26.7° 1129.03
mm
°C
Relative humidity
1920-1930
(Weather Bureau, 1962: 106-12, 106-13).
26.7° 1137.92
mm
200
100
80
60
40
20
°C
40°
10°
J F M A M J J A S O N D
1931-1955
(Smedley, 1961: 12).

FIGURE 20.



Yearly Rainfall figures, ten-year running average (from Stone 1941).

FIGURE 21.



(Jordan & Cosner 1974:7)

Accumulated departure from average, ten-year running average, and annual rainfall at Charlotte Amalie.

1930's. Jordan later indicates in a 1977 article that St. Thomas may be entering a period of deficient rainfall, or drought.

Whether the decline in rainfall is recent and temporary in nature, or is a return to the norm after a period of heavy rainfall in the 1800's, is a debate that has yet to be settled. But the fact remains that a minor change in average annual rainfall has occurred since the turn of the century, and this undoubtedly has had an effect on the hydrologic cycle of St. Thomas. The degree of impact has yet to be shown. Jordan has noted:

> "The mountain basins with their small area and small ground water storage capacity are particularly sensitive to variation in rainfall, in terms of streamflow and ground water levels. A decline in rainfall means less frequent topping off of the aquifer." (1972:D216).

And as stated by Jackson, in areas where water supply is marginal, any variability has great significance. (1977:48). However, Jordan infers in his article "Landuse Effect on the Water Regimen of the United States Virgin Islands" that the impact of this climatic change to the water regime is minor in comparison to the impact associated with the changes in land-use. (1973:D216). While the data presented here supports Jordan's observation that a minor climatic change has occurred, the decade since the publication of Jordan's articles has seen a slight increase in annual rainfall. Average annual rainfall for the period between 1970 and 1980 was approximately 48 inches, as compared to the 40 inch average for the 1960's. (Daily News, 1980:B-8). It is suggested that the changes in rainfall amounts over the past century are natural fluctuations, which have had minimal impact on the ecosystem. These fluctuations clearly show periods of increasing wetness or dryness, but no periods of long-

term drought can be established.

4.3: THE FLOW OF WATER: RUN-OFF AND SOIL ABSORPTION

When a rain storm hits St. Thomas, several factors come into play in determining how much water will run off, and how much will be absorbed into the soil. The intensity of the storm, the permeability of the soil, the surface cover, and the size and slope of the drainage basin are all inter-related factors. Storms in St. Thomas are generally short and intense and occur over areas with extreme slopes and shallow basins. This encourages a rapid run-off during rain showers, allowing less time for infiltration. An important modifying factor is the permeability of the soil and the type of surface cover, as the ability of the soil to absorb moisture is directly tied to the surface cover. The soil types in St. Thomas vary, but soil is generally high in clay content and poorly drained.

The infiltration capacity is moderate at best, and has been changed since historic times. Deforestation of the island in the late 1600's resulted in a rapid erosion of the upper layers of soil. According to Jackson, "as the soil loses its humus content it becomes less moisture retentive, and hence rainfall is less effective..." (1977:128). Removal of the well-structured, humic layers reduced the infiltration rate and led to increased run-off. While the re-establishment of vegetation provided some form of soil stability and decreased the erosion and run-off factors, a lasting damage had been done to the infiltration capacity and nutrient quality of the soil.

Surface cover can provide a modifying factor on steep terrain in terms of rate of run-off and soil moisture absorption. "A rainstorm in

a catchment of scanty vegetation will tend to produce a greater total volume of streamflow with a more marked peak than if it occurred over an area of dense vegetation." (Jackson, 1977:101). A direct relationship occurs between the percent of ground covered by vegetation and the amount of run-off in a given area. In tropical areas, the rain forest cover is most effective in terms of aiding soil absorption and slowing down run-off rates. The dense and layered nature of the vegetation slows down the intense rainfall, and more time is allowed for water to inflitrate. In addition, the vegetation provides a thick matt of roots, aiding in the capacity of the soil to absorb water. Therefore, a surface cover of scanty vegetation will allow run-off to occur at a more rapid rate, and on a paved or barren surface the run-off will be greatest. This has been illustrated by a study in Tanzania where two steep, adjacent slopes were analyzed in terms of the relationship between surface cover, erosion, and run-off rates. One slope was forested, one cultivated, and in the first two years the sediment load of the cultivated area had doubled that of the forested area. Streamflow for the forested area was 1%, compared with 3% for the cultivated area. (The relatively high infiltration rate of the cultivated area was due to the agricultural burning, which provided a fertile and highly permeable ash layer). (Jackson, 1977:105).

4.4: EVAPOTRANSPIRATION

As previously illustrated in the water budget, the greatest loss of water occurs through evapotranspiration. Different plants require different levels of water and transpire at different rates. Consequently vegetation associations will, as a group, transpire different amounts of water. Factors such as rooting depths, density of plant cover, and

ability of the plant to resist evaporation are important in determining evapotranspiration rates. The landscape in St. Thomas contains several different vegetation associations, each with its own ratio of water use. The moist and wet forest areas, due to their dense vegetation will utilize and transpire a high proportion of rainfall. However, more water will be absorbed into the soil due to the nature of the forest vegetation, and more water will be available for use. In addition, the dense vegetation slows down the intensity of rainfall, creating a reduction of stormflow that aids in soil stability, permeability, and the consequent production of a dry season storm flow. (Jackson, 1977:201).

The dry forest associations are generally more xerophytic, and adapted to drier conditions. The root depths in the scrub forest often will reach 20 feet, and this type of vegetation is able to utilize and transpire more water. The dry forests are not as dense as moist or wet forests, and more run-off occurs. Consequently, the production of a dry-season storm flow is less common in areas fed by the more xerophytic and sparsely vegetated associations of the dry forest zone.

Evapotranspiration in the swamp areas of St. Thomas is high, due to the combined factors of water available for direct evaporation at or near the surface and the associated plant species that transpire a high degree of water. When the drainage of a swamp occurs, the water lost by transpiration is lessened. However, as discussed by Jackson (1977:212), swamps tend to regulate the stream flow, and by draining the swamp the flow will become less regular and storm flow more intense.

The other major form of vegetation cover is grass and crop land. The occurrence of grass and crop land is largely related to land-use

activities such as grazing and cultivation. The low rainfall and natural soil structure accentuates aridity for the shallow rooted plants found in this area, as water is able to penetrate to lower levels and the roots rarely extend beyond a depth of three feet. (Jordan, 1972:D215). Without regular maintenance of the pasture or crop land, succession will occur, favoring the more deep rooted bushes and trees such as acacia. (Jackson, 1977:135). While a dense grass or crop cover is an efficient means of maintaining the water balance, it is seen that the effects of overgrazing or intense cultivation will result in a lowering of the water storage capacity. This will occur when the land-use exposes bare soil. Excessive trampling by stock or indiscriminate burning practices associated with agriculture, results in the destruction of soil structure, and lowers the infiltration rate of the soil. (Jackson, 1977:172).

4.5: SUMMARY

This section has described the natural landscape of St. Thomas and has illustrated how the hydrologic balance has been changed. It has been demonstrated that a marked change in the streamflow of St. Thomas is due to a combination of factors, predominantly relating to land-use and landscape modification. An increase in the amount of run-off, a decrease in amount of water absorbed into the soil, and a subsequent extension of the more arid associations of the dry forest zone have served to create an increase in evapotranspiration. This factor is of great importance to the hydrologic flow, as the majority of the water is lost in the cycle through evapotranspiration. Therefore, it is concluded that land-use activities resulting in a change to the surface cover, and a subsequent increase in evapotranspiration have played a major part in changing the

hydrologic cycle. To quote Jordan (1972:D214): "Land-uses in the mountain basins is believed by the author to exert greater influence on stream discharge than do topography, geology and to a degree, even rainfall..."

PART TWO:

LAND-USES AND LANDSCAPE CHANGE;

ST. THOMAS CULTURAL HISTORY

CHAPTER FIVE: HISTORIC OVERVIEW INTRODUCTION

While the relationship between land-use practices and hydrologic change in St. Thomas has been illustrated here, and briefly summarized elsewhere (i.e. Jordan, et al, 1972, 1973, 1977; Peebles, et al, 1979; Rivera, et al, 1970), the question of what caused these changes in land-use has been neglected.

The following historic overview section will document the change in the island economy from a locally oriented way of life, directly affected by changes in the environment, and somewhat regulated by that environment; to the current pattern of life. In this current pattern, dependence upon a foreign economy is complete in every aspect from the importation of food and water to the provision of employment.

This social/historical approach is taken to better understand those aspects of culture change tied directly or indirectly to land-use change; changes that have affected the hydrologic balance of St. Thomas. While the prehistoric and historic eras are briefly summarized, a detailed approach is taken in describing the culture and cultural change in the 20th century. This emphasis has been placed on recent activities because, in terms of land-use change and impacts to the hydrologic cycle, it has proven to be the crucial period of change.

As suggested in the introduction to this thesis, there is a direct relationship between economic change and physical environmental change. When change occurs at too rapid a pace, the culture is unable to perceive the impacts of its actions until a crisis situation has developed.

This section focuses upon the recent history of change, illustrates how the pace of change has increased and identifies what caused the current problem of water to evolve.

CHAPTER SIX: ST. THOMAS PREHISTORIC ERA

The prehistoric era on St. Thomas dates from 3500 BP (before present: 1950) to the 1500's. During this time three major forms of subsistence and land-use occurred, an analysis of which is based upon evidence found in archeological sites scattered throughout the island. (See figure 22).

6.1: PRECERAMIC PERIOD

The earliest known inhabitants were hunter-gatherers, whose exploitation of marine, floral and faunal resources occurred intermittently over a period of 650 years. Their settlements have been found in the littoral zone, lacking ceramics and, it is inferred, agriculture. The major food resources were found in the marine environment. Shellfish were exploited, and the middens are characterized by species of Arca, oyster, Gastropoda and Mollusk. The dominant species represented were Arca zebra and Pinctada imbricata (N. Atlantic pearl oyster), and the stratigraphy of the midden indicates a dual use, changing to an emphasis of one, then the other, and so forth. (Lundberg and Pearsall, N.D.).

While wood artifacts have long since deteriorated, it is assumed that being fishermen, the people used the hardwoods of the island for boat construction. Plants were also utilized, for food and for twining into ropes, nets and hammocks. Rocks were shaped and used as tools, beads and ceremonial objects. Little else is known about these people, their lifestyle, population size, or length of settlement. The only preceramic group of sites on the island are found at Krum Bay.

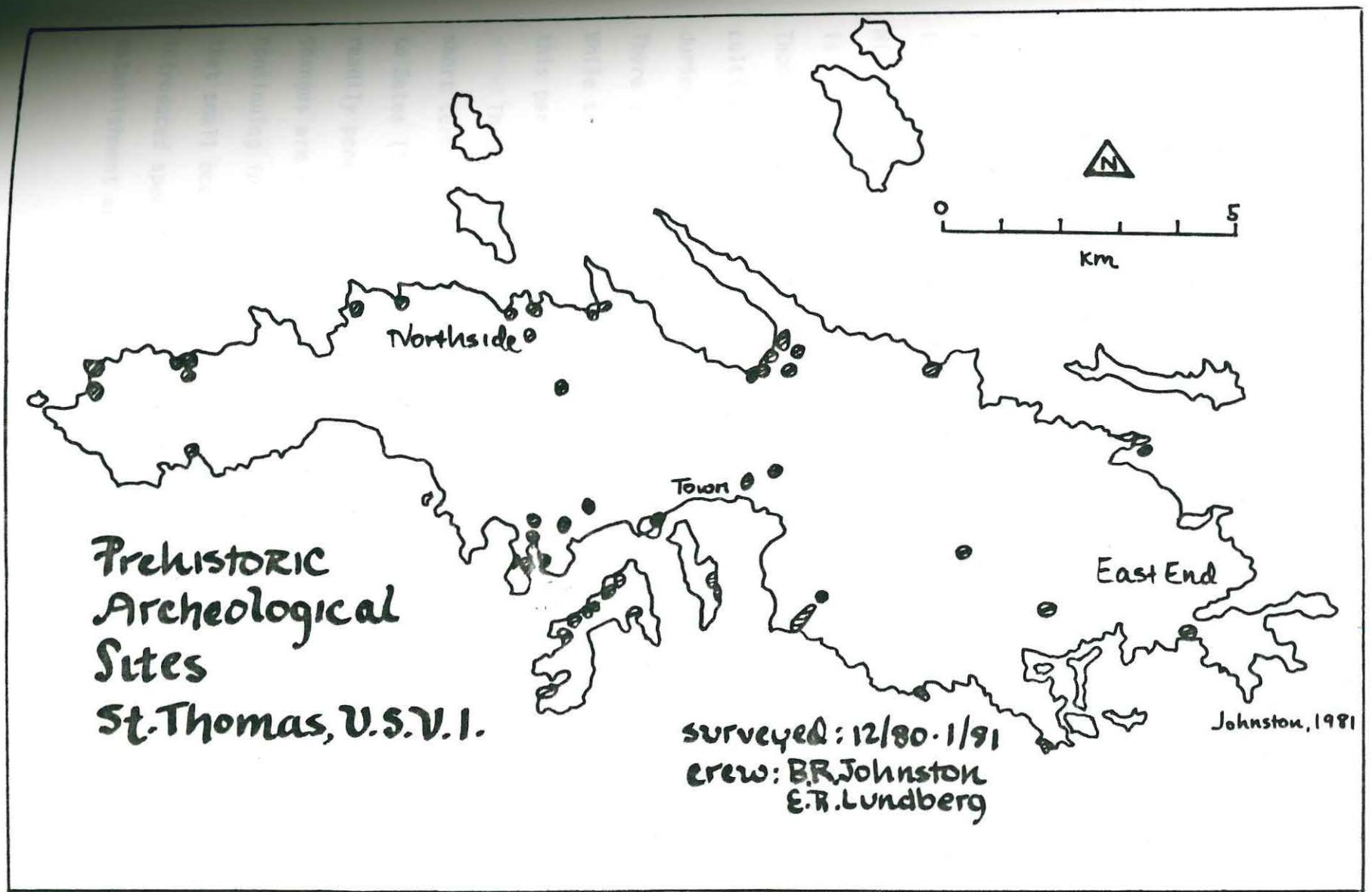

N
0
5
Km
Northside
Town
East End
Prehistoric
Archeological
Sites
St. Thomas, U.S.V.I.
surveyed: 12/80-1/91
crew: B.R. Johnston
E.R. Lundberg
Johnston, 1981

FIGURE 22.

6.2: SALADOID PERIOD

The next period of occupancy occurred between 100 and 900 A.D., and is known as the Saladoid period, a name referring to the type of pottery found in the archeological sites. There are only three remaining sites on St. Thomas from this period. However, larger sites are found on the neighboring islands of St. John, St. Croix and Vieques. Typically, the villages are found more inland than the earlier preceramic sites and are located along fresh water sources and fertile soil areas. Along with the introduction of pottery, a distinct agricultural emphasis is apparent. Middens reflect the change in resource use, and the bulk of shell material is considerably smaller (Lundberg, 1980:2). Human activities on St. Thomas during this period are associated with the practice of shifting cultivation. Due to the small number of sites that represent occupation during the 800 year period, it is suggested that settlement was sporadic. There is little evidence to support major villages of long term duration. While the introduction of alien plants is first known to occur during this period, the impact to the native plant community was fairly minimal.

This conclusion of minimal impact is based upon the assumption of short term use and long periods of relatively limited activity. According to Bates (1970:233-234), established biological communities are not readily penetrated by new species of plants and animals. Anthropogenic changes are in large part temporary and reversible, dependent upon the continuing intervention of human activities. While it has been shown that small oceanic islands are particularly vulnerable to invasion by introduced species of plant and animal life (Elton, 1958:77-93), the establishment and succession in the community is dependent upon the par-

tial or complete destruction of the native communities by humans. (Harris, 1966:142).

6.3: ELANOID PERIOD

By 900 A.D., the characteristics of the archeological sites change, reflecting changes in the settlement and land-use patterns. Pottery sherds of the Elenoid type are commonly found in large village and special use sites, located in the littoral zone. The number of archeological sites increase, reflecting a more intensive settlement history during this period. While agriculture is still an important factor in the economy, a re-establishment of the utilization of marine resources is seen. The middens consist of larger quantities of shell and fish remains, though not in the great quantities found in the preceramic sites. (Lundberg, 1980: 2). Manatees, hutias, rock iguanas, sea turtles, flightless rails, and an insectivore (Nesophontes sp.) have all appeared within archeological context, and were important factors in the prehistoric environment. These animals were exploited to the point of extinction. Figueredo, 1978:39-45). Maize, manioc, sweet potatoes, tania, peanut, common bean, lima bean, and annual peppers are all cultigens derived from wild species of the Tropical American mainland (Sauer, 1950) and were cultivated by the island population. Other plants cultivated include pineapple, guava, sweet and sour sop, hog plum, mamey, tobacco, calabash gourd, and shrub cotton. (Roumain, 1942:68-70).

6.4: SUMMARY OF LAND-USE AND LANDSCAPE CHANGE IN THE PREHISTORIC ERA

The introduction of alien species had its impact on the native plant communities and many of these plants are still found today in the fields and roadsides. Of more serious consequence was the method of introduction

of plant species. The practice of shifting cultivation requires the clearing and burning of land, planting and harvesting for a few seasons, and then allowing the land to lie fallow until the cycle is started again. In the mainland area, the people would move from field to field, thus minimizing the impacts to the soil. However, due to the lack of cultivatable land in St. Thomas, it is more than likely that during the Elanoid period the same fields were cultivated year after year. This would cause a serious depletion in the mineral content of the soil, as well as affect the nature of the surrounding plant communities. In Charles Bennett's book, Man and Earth's Ecosystems (1975:276), Bennett estimates that the majority of the Caribbean islands at the time of contact were vegetated by secondary plant communities rather than the climax community, a result of the prehistoric agricultural practices.

In addition to the introduction of aliens, the prehistoric occupation of the island resulted in changes to the vegetation. Many natural species were exploited for food, timber, and other purposes, with consequent local effects on the distribution and abundance of species. Recorded use of the seagrape and cocoplum indicates an accidental or deliberate extension of distribution along the shoreline. (Harris, 1966:76). Selective felling of large trees for houses and canoes produced another direct impact to the environment. (Roumain, 1943:31).

The evidence of human activity and cultural impact during the prehistoric period is, admittedly, scarce. However, by analyzing the archeological remains, and utilizing ethnographic and historic accounts of native lifestyles on the surrounding island, several patterns can be perceived.

The social/political organization in the prehistoric period was fairly simplistic and local in nature, serving to sustain the existing traditions and culture. Change occurred at a slow pace, mostly through outside pressures such as population movement. At the time of historic contact the Carib Indians were migrating up through the Antilles chain, warring with and conquering the Arawak culture. It is probable that where major cultural changes occurred such as the shift from fishing and gathering to slash and burn agriculture, the process of change was through the migration of a foreign population or culture.

The economy, or way of life, in the prehistoric period evolved from a fishing and gathering subsistence to an agricultural based economy and then again to a renewed fishing emphasis complimented by agriculture. Trade occurred between islands, as evidenced by artifacts not local in origin. The nature of a fishing economy requires some technological skill. Local fibers were processed and nets used to capture fish. Hammocks were used, the word itself is of Carib origins. Along with the establishment of agriculture, came the shaping and firing of clay. Pottery used for both practical and ceremonial purposes can be found at the later prehistoric village sites.

The prehistoric economy can be summarized as a society dependent upon the exploitation of local resources, in which trade with other societies occurred for social or political reasons. It was an era of change from the introduction and adaptation to a rich, oceanic environment, to the beginnings of conscious alteration of that environment.

CHAPTER SEVEN: THE HISTORIC ERA

The historic era of St. Thomas can be broken down into several periods: the early historic (1493-1672), plantation (1672-1733), trade (1733-1848), and the Post Emancipation period (1848-1917). The period between 1917 to the present is treated as a separate chapter entitled "Recent Times".

During the historic era, culture change occurred sporadically, economic prosperity fluctuating with changes in the European and American political and economic scene. An atmosphere was created whereby the local economic and political structure was dominated by external pressures. Population levels during the historic era experienced rapid increase and decline, changes which are correlated with the economic prosperity of the island. Land-use reflected the European demands for tobacco, sugar and rum, and later, the support of a town devoted to shipping and trade.

This section will illustrate that landscape change during the historic period was intense on many levels, and yet, the impact to the hydrologic cycle was relatively minor.

7.1: EARLY HISTORIC PERIOD (1493-1672)

It is undetermined how long the natives continued to occupy the Virgin Islands. After Columbus' voyage of 1493 when he visited and named the Caribbean Islands, the Virgin Islands were rarely visited by Europeans. By the 17th century the islands were considered to be uninhabited. During the 1550's, an edict by the Spanish Emperor Charles V allowed the colonials to treat the Caribbean natives as enemies and

exterminate them. (Knox, 1852:18). Through the raiding of villages for slaves to work in the Spanish mines, the official policy of extermination, and the introduction of diseases, a very small number of Europeans managed to reduce a population of thousands to the point of extinction in just over 100 years. The surviving natives fled southward to the islands of Dominica and St. Vincent. A few Carib indians are now living in a government reserve on the island of Dominica.

Settlement during this early historic period was temporary in nature. The inability of the Europeans to adapt to the climate and terrain was one factor, but more important was the state of the European economy. At this time the emphasis was on obtaining mineral wealth. Because of its lack of mineral resources, St. Thomas was left uninhabited. Occasional use of its protected harbors was made, and it is likely that timbering occurred to make repairs to ships.

The earliest attempt to colonize the island is unrecorded, but when a small company of French settlers landed in 1647 on St. Thomas, they found an already cleared plantation with mature bananas, oranges, citrons and lemons. (deBooy and Faris, 1917:46). Denmark attempted to settle the island in 1665 with Erik Smit as the leader of the Danish West Indies Company colony. The attempt was short lived due to the unpreparedness of the settlers, death of their leader, and frequent raids by the British. In 1672, a second attempt was made by the Danish West Indies Company, this time succeeding due to a treaty with Britain allowing the Danes to colonize the island without arousing British opposition.

7.2: PLANTATION PERIOD (1672-1733)

With the colonization of St. Thomas came the introduction and establishment of plantation agriculture. The European price of sugar resulted in an emphasis in growing sugar, which also meant the production of rum. In order to provide the necessary labor, slave trade was encouraged, and St. Thomas became the center marketplace for the West Indies due to the Danish West Indies and Guinea Company's monopoly. The neutral status of Denmark, as well as the trading opportunities provided by the Brandenburg Company allowed St. Thomas to become the focal point of the West Indies. By 1691, 101 estates were planted. In 1707, the island was described by Pere Labat as "a market of great consequence. The town is prosperous, the estates small but well kept." (Knox 1852:62-63). In 1715, 160 plantations were producing sugar and cotton, 32 estates had their own wind-powered sugar mill. In 1724, the island was declared a free port, a status that was to be held intermittently over the next century, and the population of the town grew rapidly. Intensive cultivation and rapid population growth created a prosperous environment. By 1725 the island had a population of 4814, living on 177 plantations. Of this total, 324 people were white. The proportion of slave to master was high, and out of fear of revolt, heavy regulations and fines were imposed. A series of disasters ended in revolt by the half starved slaves of St. John in 1733. As evidenced by this revolt, the island economy was highly susceptible to growth regulating factors such as natural disasters. The events proceeding the revolt included a drought during the spring and summer, a hurricane in July, a plague of insects in the late summer, wiping out most of the crops, and an autumn storm destroying the maize

crop. Slaves were expected to grow their own food and, when the planters ran short, they imported provisions for themselves, but rarely anything for their slaves. Tension was high, and the white population was uneasy about the ever increasing proportion of blacks to whites. The insurrection was put down, but the fear of revolt heightened.

7.3: TRADE PERIOD (1733-1848)

In 1734 the Danish West Indies and Guinea Company ceased its part in the trade of slaves, ending a fifty year monopoly on the trade and encouraging the continuing growth of St. Thomas as a trade center. Maximum cultivation of the island had been reached in 1720, and the acreage of land cultivated each year declined. (Evans, 1945:169). The effects of sugar production year after year served to deplete an already depauporite, or nutrient-poor soil. In 1732 Moravian missionaries had arrived to civilize the savages. The policy of the missionaries was to preach and teach to the slaves, while working with them. The end result of this was missionary-run plantations, where the preacher purchased his slaves to work the land and enlarge his spiritual flock. (Furley, 1965:4).

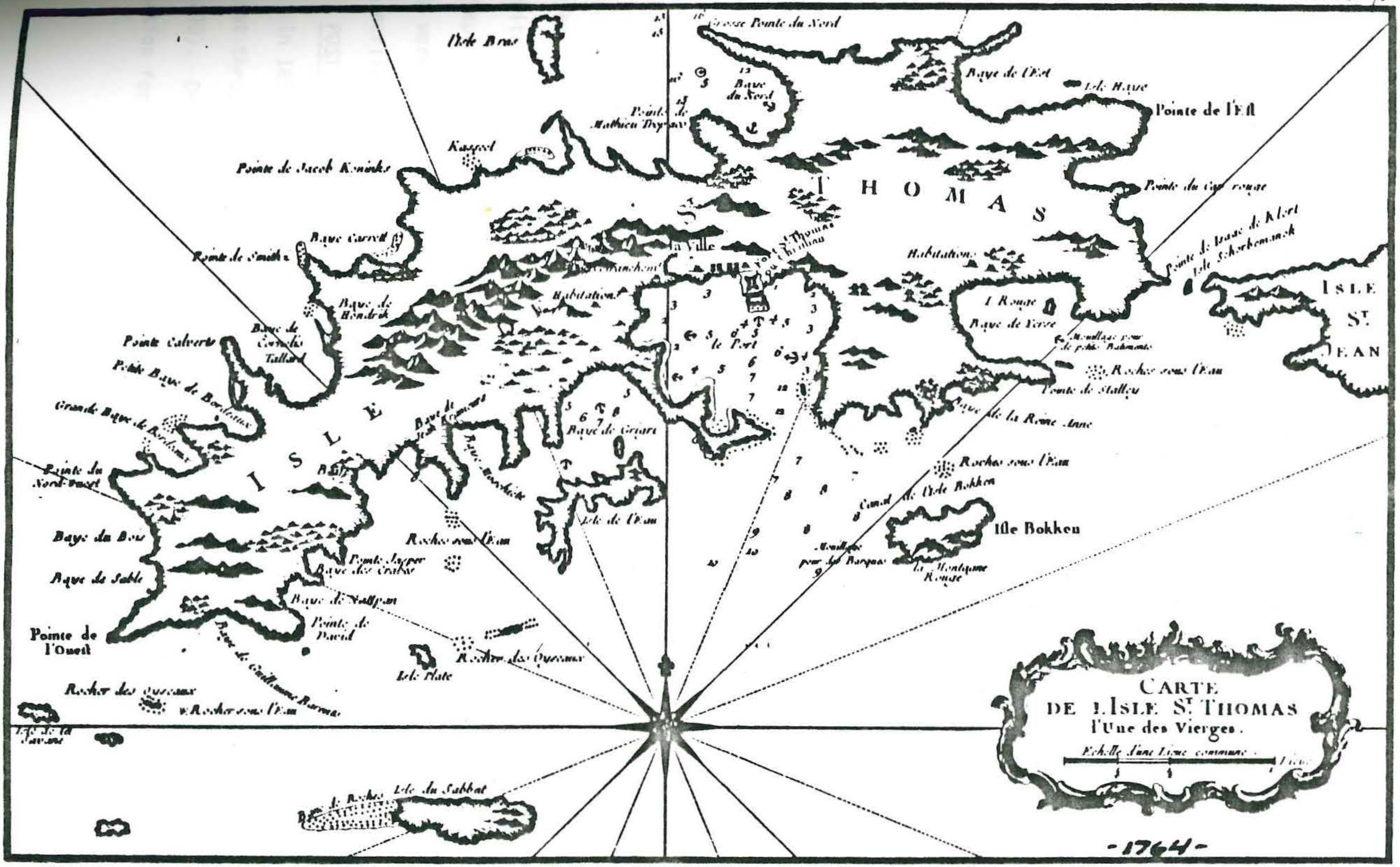
With the Danish purchase of St. Croix in 1734, hundreds of families left St. Thomas to cultivate the fertile soils. The history of intensive cultivation had led to the depauporite condition of the soil and hence the production of sugar in St. Thomas was on the decline. At the same time, the Danish West India Company had many fiscal difficulties, terminating in bankruptcy in 1754. The Danish government purchased the company and the island became a Royal Crown Colony. When the king took over, Europe was on the verge of war over the control of India, Canada and the West Indies. As a measure of importance of the West Indies colonies, at

the end of the war, Britain agonized over which territory to concede to France--Canada or the island of Guadelupe. (Westergaard, 1917:157).

In 1755, there was again an exodus to St. Croix. In 1756, there was not one Danish vessel reported stopping in St. Thomas. Trade was at a low and citizens sent a delegation to Denmark to ask that it be made a freeport. Ten years later the port was declared free to trade with all nations, and commerce again picked up. The status of freeport was intermittent over the years, due to its ties with Denmark and the ebb and flow of imperialistic conquest. The many small, secluded bays on St. Thomas allowed for the support of a lucrative smuggling trade which flourished in times of trade restrictions. (See figure 23). The American revolution in the 1770's served to stimulate St. Thomas commerce, since through trade and smuggling much of the Americas were provided with European goods. In 1789, a three year drought forced many planters to sell their slaves. In 1792, Denmark became the first country to abolish the legalized slave trade. The ending of legalized slave trade was a sure indication of the change in the status of agriculture in the colonies. "As long as the demand for sugar and cotton made it profitable to raise those products, just so long would there be a slave trade." (Evans, 1945:155).

Toward the end of the 18th century, St. Thomas' importance and prosperity had declined. However, the last decade of the century saw great change in the population and commerce. A combination of the French Revolution, Spanish political unrest and the neutral status of Denmark created a boomtown in St. Thomas. Immigrants and political refugees were attracted to the only freeport in the West Indies. By 1799, there were more than 7000 people living in the town. A series of fires and epidemics wiped out

FIGURE 23.


CARTE
DE L'ISLE S.T THOMAS
l'Une des Vierges.
Echelle d'une Lieue commune
ISLE S.T THOMAS
Grosse Pointe du Nord
Baye du Nord
Baye de l'Est
Pointe de l'Est
Isle Bokken
Canal de l'Isle Bokken
Rochers sous l'Eau
Baye de la Reine Anne
Pointe de Stalley
la Ville
le Port
Habitations
Baye de Gorare
Isle de l'Eau
Pointe de Jacob Koninks
Pointe de Smith
Baye Carvell
Baye de Hendrik
Pointe Calverts
Petite Baye de Bordeaux
Grande Baye de Bordeaux
Pointe du Nord-Ouest
Baye du Bois
Baye de Sable
Pointe de l'Ouest
Baye de Nallpan
Pointe de David
Isle Plate
Rocher des Oyseaux
Isle du Sabbat
Isle Bras
Kassel
Pointe de Mathieu Dryson
Isle Rouge
Baye de Verre
la Montagne Rouge
ISLE S.T JEAN
-1764-

portions of the town in the next year, but each time it was rebuilt more prosperous than before. By 1819, there were over 13,000 people in the town of Charlotte Amalie. Minor fluctuations in the overall prosperity occurred when the British held the island in 1801 and again from 1807 to 1815, closing its freeport status. The war of Spanish Independence (1808-1825) created a beneficial trade climate for St. Thomas. By 1835 there were 14,000 people living on the island, and only 2500 cultivating the plantations. (Weinstein, 1962:39). In 1837, the first bank on the island was opened. The Bank of St. Thomas (1837-1898) paid a dividend of 12% within six months. By 1840, 80% of the population was involved in trade or commerce. (O'Neill, 1972:30). The first half of the 19th century marked a period of increasing growth and economic prosperity, a state which continued up until 1848. Population was now centered in the town, with plantation activity oriented towards supporting the town and provisioning the ships rather than the European market.

In 1847, laws were passed for the emancipation of slaves, allowing a 12 year adjustment period. A deteriorating relationship between blacks and whites in the island led to a revolt on July 2, 1948, in St. Croix that rapidly spread to St. Thomas. Soon after taking over the towns, the slaves were declared free, ending an era of trade built upon the profits of an earlier plantation society.

7.4: POST EMANCIPATION PERIOD (1848-1917)

In 1854, it was estimated that 25% of the effective working force was lost through emigration in the six years since emancipation. (Dookhan, 1976:240). Despite the social instability and labor problems, St. Thomas' reputation for trade continued to climb. St. Thomas in 1867 was the center

of freight shipping. The harbor had all the facilities for shipping, namely coal stations or bunkers for refueling, wharves for unloading, tanks for watering and a floating dry dock. But a climax had been reached, and the population suffered from the effects of natural disasters.

In 1853, 100 people died from malaria. In 1853-54, cholera killed 1865. Another cholera epidemic killed 1200-1300 people in 1866-67. In an attempt to relieve the overcrowded harbor from its state of stagnation, a second channel was cut in at Frenchtown in 1867. Shortly after, a hurricane hit the island, coming in from the North and destroying the previously protected harbor. This disaster was followed by an earthquake and a tidal wave, and resulted in an entire harbor filled with wrecked or sunken ships. In 1871, two hurricanes hit the island, destroying 400 houses. (Dookhan, 1976:220). Its reputation of natural healthiness and a safe harbor was tarnished, and in 1871, shipping companies began to contemplate alternatives to the entrepot in St. Thomas. The establishment of telegraphic connection with Europe and the U.S. obviated the necessity for current market information to go through St. Thomas. In 1885, the Royal Mail Steam Packet transferred their West Indies headquarters to Barbados. Due to the crowded port, a harbor too shallow for steam ships, and a one firm monopoly over the coal and water supplies on St. Thomas, many other firms followed the Royal Mail Steam Packet Company to Barbados.

The cultivation of the land had basically ceased by the end of the century. In 1908, there was one sugar mill on the island, and it was not in operation. (Westergaard, 1917:255). St. Thomians were surviving through the raising of livestock, cutting of wood for charcoal, and the provisioning of coal to the occasional steamer. Sabra Holbrook wrote in The Ameri-

can West Indies:

> Although the government remained Danish, the people were left pretty much alone. They raised pigs, chickens, goats, and some cattle. They grew vegetables. They fished. When the sea receded from inland ponds, they took the salt it left. They burned charcoal for cooking fuel, as they had always done...If a storm or drought destroyed what they had, they began over again, perhaps on another hillside. (Holbrook, in O'Neill, 1972:36).

By 1916, the islands were $3.75 million in debt to Copenhagen and operating at a loss of $190,000 a year. A Royal commission report in 1916 recognized a long list of actions necessary to make the islands self-sufficient at a cost of $2,240,000. While a few changes were instituted, the economy continued to decline. In 1916, in what was considered excellent military strategy against the Kaiser's threat, the U.S. purchased from Denmark the Virgin Islands for $25,000,000. (Evans, 1944:36-37).

7.5: SUMMARY OF LAND-USE AND LANDSCAPE CHANGE IN THE HISTORIC ERA

Resource use in the plantation period created dramatic and lasting scars to the landscape. The prehistoric agricultural practices had required the clearing of small plots, and short periods of cultivation. The plantation system resulted in the clearing of most of the forested land through fire and an intensive cultivation of land that rapidly depleted the soil nutrients. The colony was settled in 1672; by 1670 most of the island was cleared and divided into estates. (See figure 24). Soil erosion must have been rapid, as soil stability on the steep slopes is maintained for the most part, by the forest vegetation. Archeological sites located in the bays, particularly on the Northside of the island show a one to two foot horizon of sterile soil over the prehistoric material and under the historic deposits. (Johnston 1981).

The shift in economic emphasis from plantation to trading port had resulted in a large part of the island left uncultivated.

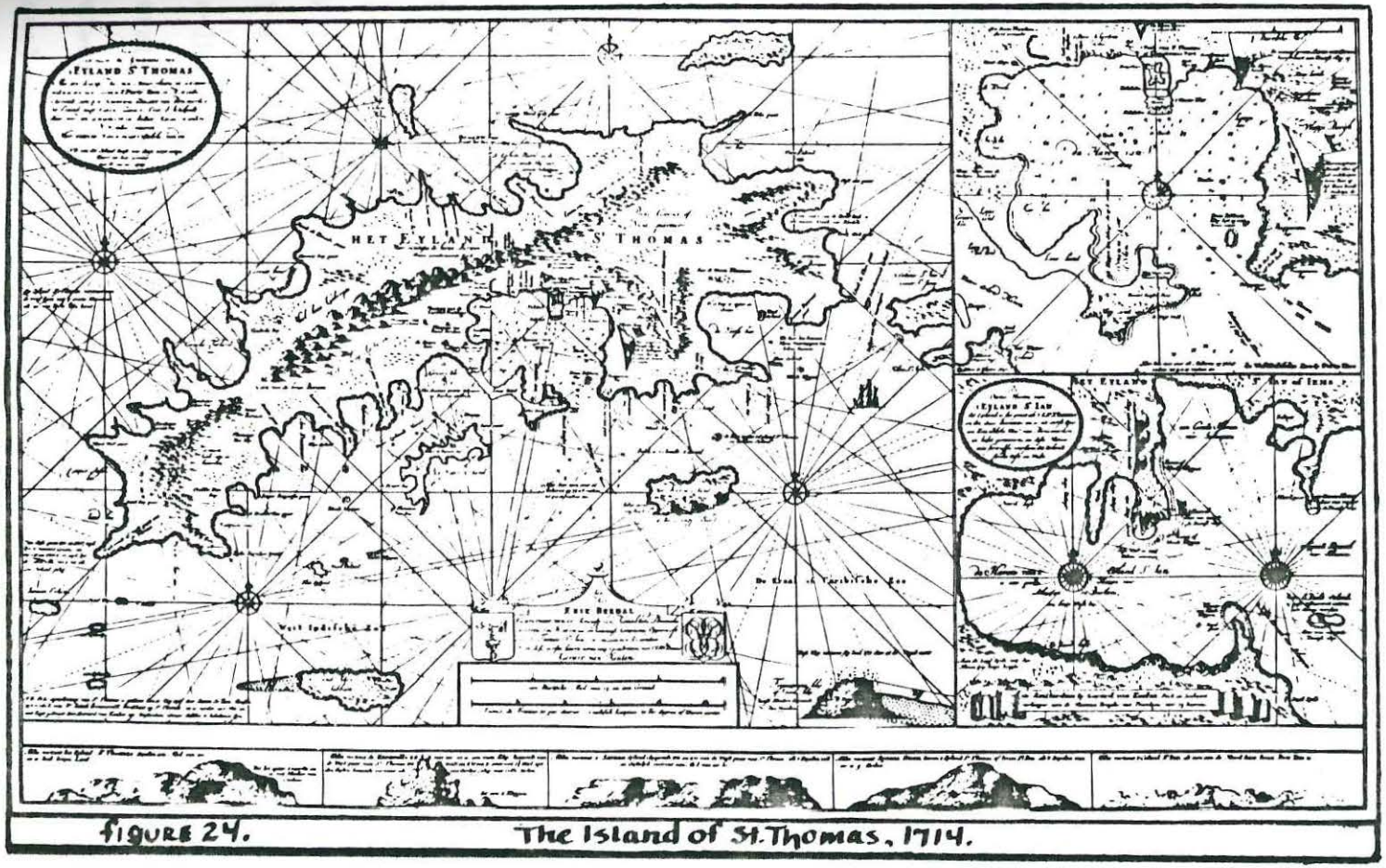


FIGURE 24. The Island of St. Thomas, 1714.

But as population grew (see figure 25), the need for food resulted in a more intensive rural use. Towards the end of the historic period much of the island was pasture for cattle and goats. Landscape modification occurred in every life zone. Coconuts were planted along the beaches, marshes were drained, and the spatial distribution of mangroves greatly reduced. Wells were built tapping the limited water supply. Stones and trees were removed to build the town, stripping the old mills and plantation great houses down to the foundations. Of the 32 wind-powered mills reported on St.Thomas in 1715, one is left standing today.

Widespread removal of the forests resulted in more xeromorphic growth once cultivation ceased, and the distribution of the dry forest and thorn scrub woodland was greatly extended. (Eggers, 1879:18). Introduced species had dramatic impacts on the plant, animal and bird populations. One such species is the mongoose, which was originally introduced to control the rat population and resulted in the rapid population of a new predator in the local ecosystem, filling in a place where none had existed before. The mongoose provided a real threat and the eventual extinction of several species of birds, iguana and rodents. (Figueredo, 1978:1).

With the establishment and growth of Charlotte Amalie, came the gradual fill and pollution of the bay. Conditions were so bad that by the mid-1800's the safest harbor in the Caribbean was so crowded with deteriorating ships and refuse from the town that the narrow strip of land between Careen and Cowells hill was blasted through to provide additional circulation to the harbor.

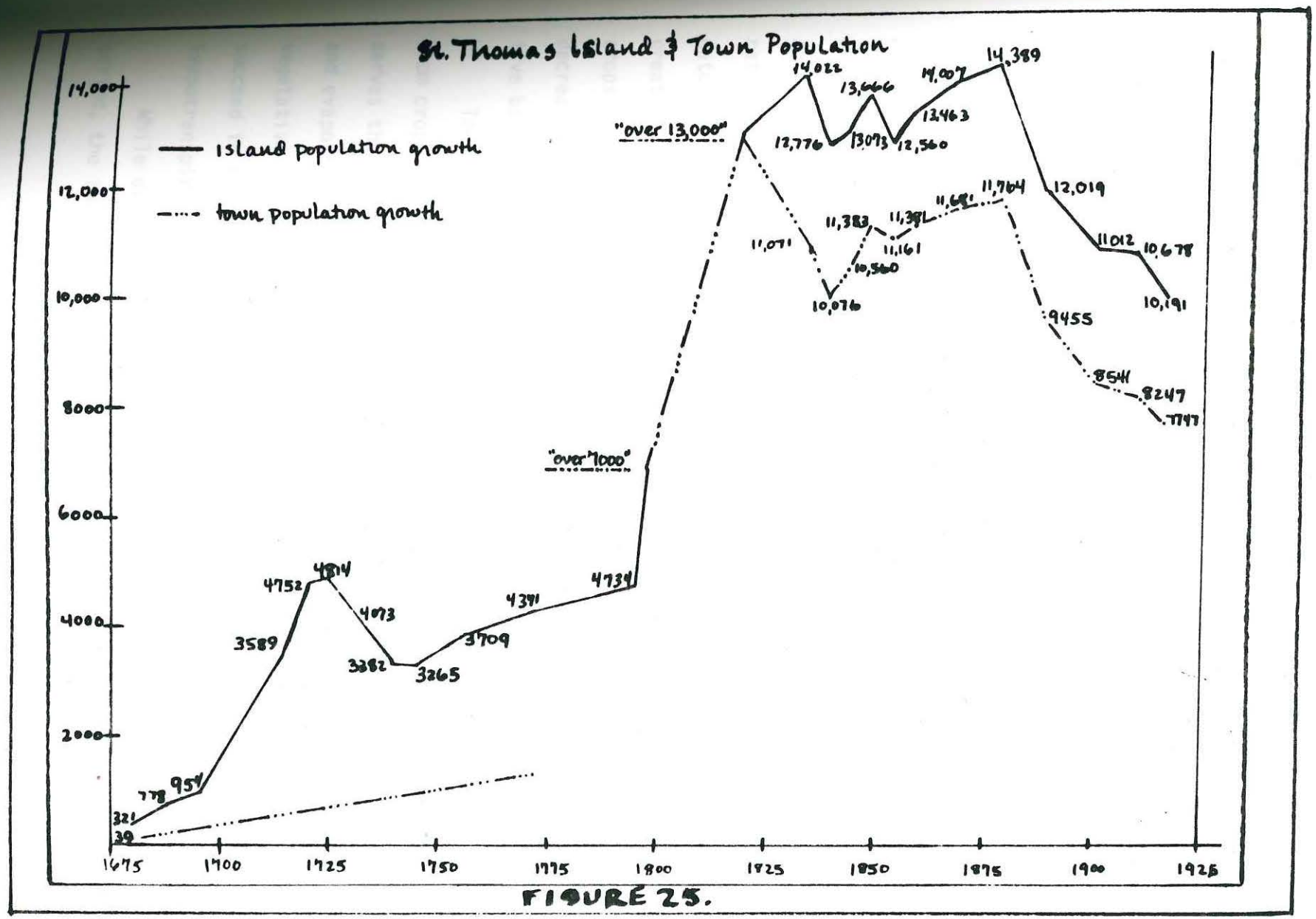

St. Thomas Island & Town Population
island population growth
town population growth
14,000
12,000
10,000
8000
6000
4000
2000
1675
1700
1725
1750
1775
1800
1825
1850
1875
1900
1925
"over 13,000"
"over 7000"
321
778
954
3589
4752
4814
4073
3282
3265
3709
4391
4739
39
14,022
12,776
13,666
13,073
14,007
12,560
13,463
14,389
12,019
11012
10,678
10,191
11,071
10,076
11,383
10,560
11,381
11,161
11,681
11,764
9455
8541
8247
7747

FIGURE 25.

By the end of the historic period, more landscape change had occurred in a 400 year period than in the previous 3000 years. And yet while expressions of historic land-use are still in evidence, the impact on the island hydrologic cycle was relatively minor.

The first section of this thesis concluded that the primary cause of change in the hydrologic cycle involves changes to the surface cover that effect evapotranspiration rates. Devegetation associated with the setting up of plantations was rapidly followed by intensive agriculture. Field crops, with the dense matt of shallow roots, served to replace the functions of the original forest cover in allowing for percolation and recharge of the aquifers without tapping the deeper sources of water. Evapotranspiration rates for forest cover are higher than cropland, but the dense, layered nature of the forest breaks the impact of heavy rains, allowing for a greater proportion of water to be absorbed into the soil. Replacement of crops for forest cover would lower the ratio of evapotranspiration and decrease the rate of absorption, resulting in the maintenance of a relative balance in terms of water availability.

Towards the end of the historic period much of the land was converted from crops to pasture for livestock. Pastureland, when well maintained, serves the same function of cropland in terms of surface cover, absorption and evapotranspiration. However, when overgrazing occurs, the soil and vegetative cover deteriorates. Pioneering plants such as Acacia sp. will succeed in the pasture and result in an extension of dry forest woodlands. Evapotranspiration rates will climb, as absorption rates decline.

While overgrazing might have occurred at the end of the historic period, the impacts of this activity would not have been felt immediately.

As Kraus (1955) noted, the last half of the 1800's was an above average rainfall period for the tropics. The impacts of land-use to the surface cover transpiration and soil absorption rates would be offset by the increase in rainfall. Not until a return to the regular level of rainfall, and a continuing misuse of the land, would the impacts of land-use be seen in the change in water availability.

DeBooy and Faris noted in 1918 that an absolute water shortage had never been known to occur on St. Thomas. It is concluded that the problem of water availability on St. Thomas, while influenced by changes in culture and land-use in the historic period, is a relatively recent problem.

CHAPTER EIGHT: RECENT TIMES

Land-use and landscape change are directly related to change in the economic and political structure. The United States purchase of the Virgin Islands marked the beginning of an era of rapid change. Population levels increased and the economic and political structure changed within a few short years from minor colonial dependence on the Danish motherland, to an almost total economic and political dependence on the United States. As the pace of change increased, so too did the magnitude of impacts. Rather than sporadic periods of development and prosperity common in the historic era, the recent period is characterized by a continual push at the federal level to achieve United States' standards of living. Economic success was to be implemented by various federal programs and incentives, and the ongoing support of failing programs and introduction of new ones caused an ever-increasing rate of change.

A detailed look at how the political and economic structure has changed is provided in the following chapters, with an emphasis on determining what caused the changes to occur. The periods of Naval Rule (1917-1931), New Deal (1931-1940), World War II and Post War (1941-1954), and current period of Tourist Economy (1950's to present) are explored, and the reasons for land-use and landscape change identified. The relationship between recent cultural and land-use change to the hydrologic cycle is then discussed.

8.1: NAVAL RULE (1917-1931)

United States possession of the Virgin Islands occurred on March 31, 1917. A territorial government was organized under a temporary constitution and administered by the Department of the Navy. This constitution

was intended to serve in the transition from the previous Danish system to an American set of laws, customs and ideals. Evans has noted: "Once a definitive constitution has been drawn up and the respective courts have rendered their decisions on moot points, the administration of a territorial possession follows more or less a prescribed pattern." (Evans, 1945:261). The temporary constitution in the Virgin Islands remained in effect for more than 18 years, and the prescribed pattern followed was one of continuing local economic decline and increasing dependence on the federal government. This chapter explores the chain of events which have instigated social and economic patterns, which in turn have led to the environmental crisis found on St. Thomas today.

In 1919, a delegation was sent to Washington D.C. to report on the conditions in the Virgin Islands and request additional financial support. Reporting to the Senate, Mr. Francis stated that only 3% of the land was owned by natives. The remaining 97% was owned by Europeans who would not sell or lease. The island inhabitants had little opportunity to make a living off the land. He further stated: "The people are approaching a condition of starvation. There is not work enough for men to support their families and they cannot secure land upon which to raise products for family support." (SR 160 [66-1], 1919).

The following decade was to see little change in the economic and social problems reported to congress in 1919. In 1927, Thomas A. Dickinson wrote an article entitled "The Economic Crisis in the Virgin Islands". In this article he summarized the economic problems of the Virgin Islands as being the result of an outmoded feudal system firmly entrenched in the economic, political and social structure. Dickinson illustrates this

point by stating:

> "In St. Thomas 60% of the total acreage is held by 15 owners. The landowners made no pretense at proper capitalist use of his land, jealously holding it...as a speculative property to be bought up at immoderate prices by wealthy American visitors who somehow never materialized." (Dickinson, 1927:318-381).

Between 1918 and 1931 over a quarter of a million dollars were annually appropriated by Congress for the improvement of the Virgin Islands, in addition to an annual average of $300,000 to run the Naval government. Large amounts were spent to cover the municipal deficits, pay U.S. expenses (administration and projects outside of the municipal budget) and provide pay and allowance for the naval and civil service personnel. (Evans, 1944:9). Evans noted: "The islands enjoy the distinction of being perhaps the most heavily subsidized of any comparable colonial possessions, certainly of any in the West Indies...The nearly self-sustaining finances of the Danes were changed by the Navy into a condition where the United States covered more than half of the local expenditures." (1944:157).

Despite the large amounts of money appropriated by Congress and used by the naval administration, little economic improvement was seen. In 1929, Congress authorized a Bureau of Efficiency investigation into the administration and economy of the island. While the report was being written the Danish company that controlled the St. Croix sugar business closed overnight, leaving a thousand people unemployed and several hundred other people directly effected. If it had not been for the Red Cross emergency food supplies, it is likely that people on St. Croix would have starved. During the 1930-31 period, about 25% of that island's population had to rely entirely on the Red Cross for sustenance. (O'Neill, 1972:47-48).

Why, if so much money was being spent, was there so little change in the economy and general welfare of the people? Much of the reason has to do with the distribution of local power. The administration was a military rule, acting under a presidential appointed govenor who had considerable power. Municipal councils which had been set up under Danish rule still existed, and the role of these councils were largely advisory. Decisions as to how to improve the Virgin Islands and the priority of funding projects fell on the shoulders of the naval government. While fair progress was made in improving health conditions, public works such as building and improving roads, and the construction of a water catchment/cistern system, the first rule of the Navy was "don't make waves". (O'Neill, 1972:47). Little was done that did not meet the support and approval of the local "royal families" who controlled the municipal councils. The emigration rate during this period attests to the social and economic problems; Lewis noted that the emigration rate during the period of naval administration rose 15% He went on to state that in 1931

> "the Virgins were substantially a depressed colonial society. Deeply rooted in an economy whose traditionally dominant occupations remained the same in 1931 as they had in 1917, estate agriculture based upon the cheap Negroe labor in St. Croix and harbor commerce based on the hard-pressed clerks and stevedores in St. Thomas, the social structure remained rigidly conservative, grossly undemocratic, and profoundly inegalitarian." (Lewis, 1972:59).

Naval rule did little to break the barriers between the wealthy and the very poor, and in many ways it reinforced the wide gap. The municipal councils which advised the administration were representative of only the very wealthy class. Under local law only males 25 years of age earning $300 per year or owning $60 worth of land in St. Croix, $140 worth of land in St. Thomas could vote. In 1920, only 321 people out of a total

population of 26,000 were eligible to vote. (HD:734 [66-2]). In 1930, less that 10% of the total population in the Virgin Islands of 22,000 were eligible to vote. (Evans, 1944:277). In many districts councilmen were elected by less than a score of voters. In testimony supporting the 1919 Senate report on the economic conditions in the Virgin Islands, it was noted that the judge of the islands was also a member of the legislative assembly that made the laws, the municipal council, the chief of police, and the collector of taxes. Evans stated that the navy did not support the idea of enlarging the autonomy of the islands, or reducing in any way the powers of the governor. (Evans, 1944:277).

Nor, it can be inferred, did the wealthy class. The two often worked together in achieving mutually beneficial arrangements or congressional appropriations. When Congress was considering the changing of department administration of the Virgin Islands, the navy government appealed to the municipal councils to send a protest delegation to Congress. The council failed to act in time and in 1931 the administration of the Virgin Islands was changed by executive order of President Herbert Hoover from the Department of the Navy to the Department of the Interior. In 1935, the municipal council, belatedly, sent a petition to Congress requesting the return of the naval administration. (Lewis, 1944:71).

O'Neill noted that: long before the word "depression" entered the statesiders consciousness, the Virgins were in one. (1972:48). About half of the work force was without employment from 1930-1933. The Department of Interior found itself responsible for the administration of a territory whose standard of living was only maintained through the liberal, and regular appropriations of Congress.

8.2: NEW DEAL (1931-1940)

In 1929, the Director of the Bureau of Efficiency, Herbert D. Brown, was sent to the Virgin Islands to make a thorough study of the government's management procedures and techniques. Brown wrote a 900 page report describing the economic, social and political status of the islands, providing a recommended program for change, and concluding with three options for Washington:

1. Let the Virgin Islands live on their own resources as the rest of the West Indies were doing.
2. Continue appropriations as they have been in the past, with the possibility of eventual progress.
3. Increase appropriations sufficiently to do "energetically and at once the things that are necessary to bring about improved conditions", with the ultimate goal of making the islands self-supporting. (O'Neill, 1972:47).

The Hoover administration supported Brown's findings before Congress, and the necessary funds were set aside for the program of rehabilitation. The New Deal in the Virgin Islands occurred two years before Franklin Delano Roosevelt was nominated for the presidency.

Brown's recommendation was accepted by Congress under the assurance that by supplying an initial large capital, the islands "in a very few years" could be made self-supporting by the adoption of an adequate tax system. (Evans, 1944:156). This did not come about as planned. In the period between 1917-1941, the United States spent some 13 million dollars on the islands, and despite the New Deal, the social welfare and economic problems remained in many ways worse than before and agricultural development through the Homestead Act was a dismal failure. The rehabilitation policy supported the development of the Homestead Act, a handicraft co-op, formation and support of the Virgin Islands Co. (a sugar industry on St.

Croix) and the redevelopment of Bluebeard's Castle into a tourist establishment. Of all these programs, only the tourist hotel at Bluebeard's castle was a success, of very minor importance to the populace. The government hotel opened in January, 1935, with rates varying between $32-70 per week. The average laborer in St. Thomas earned at that time $75 per year. (Department of Interior, 1936:22). The gap between the rich and poor was made even wider.

One of the less successful programs of this period was the attempt to encourage subsistence and cash crop agriculture. The Homestead Act was implemented in St. Thomas in 1935, and its initial success was soon dampened by the impacts of poor agricultural techniques, overgrazing and abandonment. Six hundred and ten acres were purchased by the government and then sold in lots on a twenty-year repayment plan to local farmers. An average size plot was six acres. A 1936 publication put out by the Department of Interior noted: "...though the island of St. Thomas is rather rugged for agriculture, and though few of its people have any farm interest or farming experience, a homestead project has been set up to encourage small farm development and ownership." (1936:1). Farming was only a barely viable success during the plantation period, on an average of fifty acres, with relatively fertile soils, economic demand for produce, and slave labor. The soil conditions by 1936 were poor at best, and as stated above, few people had any interest or experience in farming. Of the fifty lots sold, very few succeeded. More commonly the land was grazed by cattle and goats, cleared and burned for charcoal, or stripped of its stone to be used in town construction. The attempt to encourage agriculture had resulted in the eventual over-intensive use of the land.

Even though the government-owned companies showed little or no profit, New Deal money kept flowing to the Virgin Islands. By 1938, $3.5 million had been invested in these projects, and a climate of "Washington will take care of us" was being firmly established. The various rehabilitation schemes failed throughout to generate full employment and tax revenues had yet to match, let alone surpass the amount of federal support. The decision to establish a Marine Corps base in 1935 and a submarine base in 1939 indicated the "economy would fall back upon the medicine of locally established federal direct employment agencies." (Lewis, 1972:72).

8.3: WORLD WAR II AND POST WAR (1941-1954)

As Pearl Harbor abruptly terminated the New Deal program stateside, so did it change the course of attempted reform in the Virgin Islands. Extensive defense employment and abnormal revenues resulted in a boom-town atmosphere in St. Thomas. Almost overnight the island achieved full-time employment status, attracting laborers from the outer islands. Population skyrocketed, as did population pressures on the environment. In the period between 1931-1943, the cost of living increased 37%, as compared to a stateside increase of 26%. (Lewis, 1972:94). The neglect of local health and sanitation by the Department of Interior during the previous decade created an acute problem as the population increased. These problems were unalleviated, as, unlike past war time economic booms, the period of prosperity in the Virgin Islands was short lived.

The result of the short-term prosperity was an increase in population and an accentuation in the social and environmental problems of the island. The landlord-merchant oligarchy had survived the New Deal and been strengthened during the war. There was a high degree of monopoly as the population

continued to rely on imports. The post-war economic organization and social structure remained unchanged, except for the fact that the gap between the two classes of wealthy and poor had widened as a few people made lasting profits on the black market and thousands of illegal immigrants moved to St. Thomas in search of employment.

By 1945, the public policy in Charlotte Amalie increasingly became one of persuading Congress of their eligibility for welfare-state benefits. The idea that "Washington would provide" had prevailed through the decade. The annual governor's report for 1944 stated that:

> "As anticipated in the annual report for the preceding fiscal year, unemployment--despite the repatriation of many foreign workers who had been imported for defense construction--was the most serious consideration in the Virgin Islands during the year under review." (Department of Interior, 1944:2).

The 1945 annual report mentioned the possible importance of tourism to the economy, observing the increasing use by army and navy personnel. It later went on to express doubt that the islands "can ever become self-supporting on any permanent and sound basis..." (1945:2, 16). The 1946 report stated that the

> "...underlying economic problem of the Virgin Islands is the fact that a large amount of money is sent out of the communities in payment for food, clothes and other commodities produced abroad, while very little money comes from the outside for things that are produced in the islands." (1947:3).

While perhaps a very simplified version of the problems of the economy, the import/export dichotomy was accurate, and not unique to 1946. (See figure 26). The years after the war saw continuing economic decline and ceaseless searching by the government for an answer to the financial problems of the Virgin Islands. That answer was found in the tourist industry.

8.4: DEVELOPMENT OF THE TOURIST INDUSTRY

In 1832, John P. Knox wrote a book entitled A Historical Account of

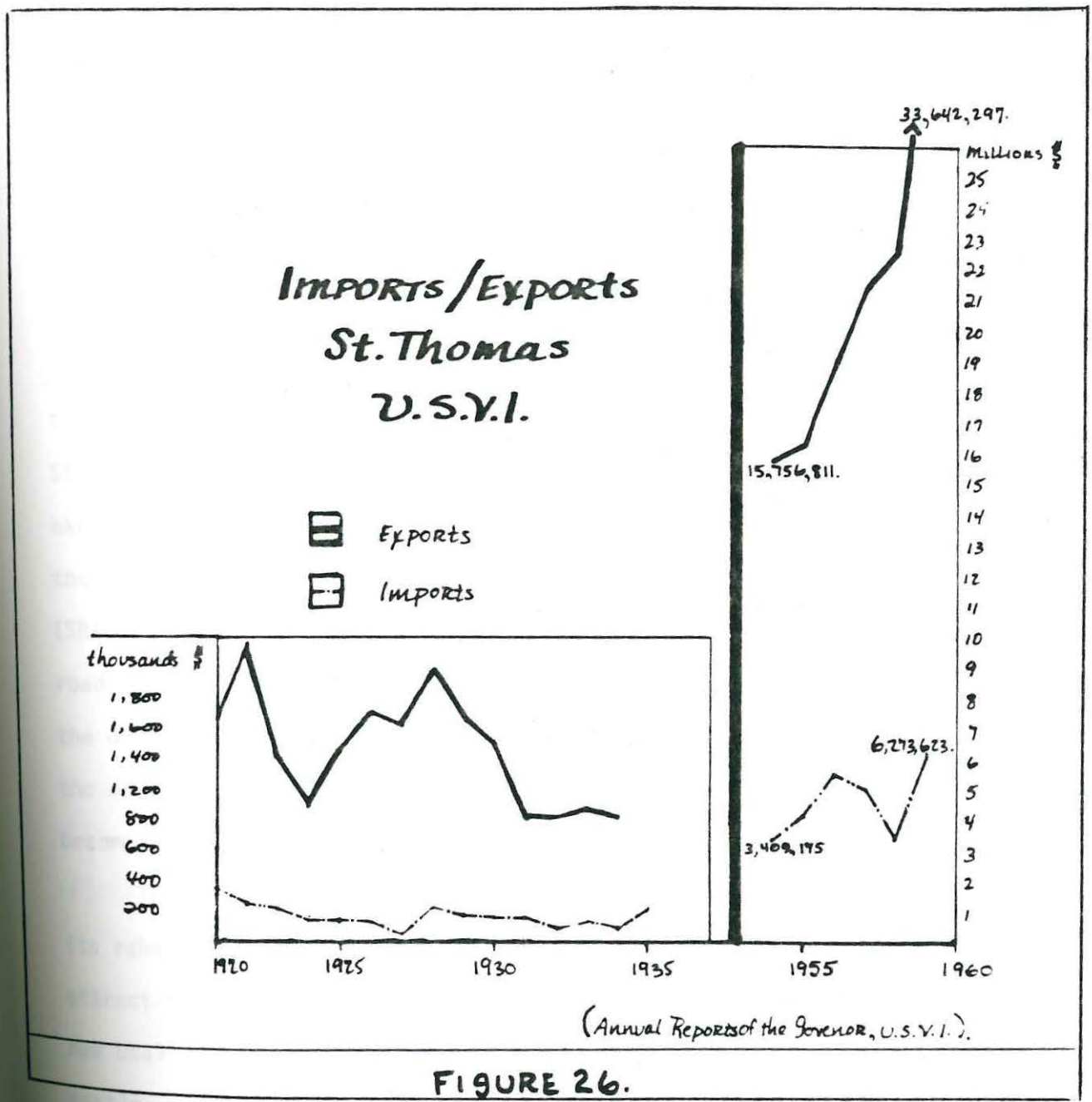

IMPORTS/EXPORTS
St. Thomas
U.S.V.I.
EXPORTS
IMPORTS
33,642,297.
15,756,811.
6,273,623.
3,409,195
Millions $
thousands $
1,800
1,600
1,400
1,200
800
600
400
200
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1920
1925
1930
1935
1955
1960
(Annual Reports of the Governor, U.S.V.I.).

FIGURE 26.

St. Thomas, West Indies. In it, he devoted an entire chapter to tourism, listing the easiest travel routes, fares, places to stay, sights to see, and items necessary to bring along. In 1918, deBooy and Faris published a descriptive account of the newly purchased Virgin Islands, with a noticeable emphasis on the encouragement of tourist visits, including a chapter entitled "Hints for the Tourist".

While economic studies of the Virgin Islands tend to place 1950 as the beginning of the planning and growth of the tourist industry (see: Virgin Islands Trade Study, 1979 and The Significance of Tourism in the U.S. Virgin Islands, 1976), the merchants of St. Thomas have long benefitted from and schemed for the growth of the tourist industry. United States policy supporting or encouraging the tourist trade is seen as early as 1919, where a report to the Senate on the economic condition of the Virgin Islands emphasized the "great possibilities in these islands". (SR160[66-1]). A 1920 Congressional Report emphasized the development of roads, which would be not only helpful to the poeple, but would support the development of a tourist trade. "With the acquisition of water and the development of good roads and hotel facilities these islands might become a great resort for the people of the United States". (HR161[66-2]).

The Bureau of Efficiency report in 1930 placed as first priority in its rehabilitation program the rebuilding of the Grand Hotel in order to attract tourists. One of the first actions and only major success of the New Deal program was the government purchase and renovation of Bluebeard's castle, creating a government-owned hotel. (The Grand Hotel was later remodeled by private parties.) The annual report of the Governor of the Virgin Islands for 1938 reported that the "hotel has proved to be a use-

ful means of attracting visitors to the Virgin Islands and has adequately fulfilled the purposes for which it was originally established". (Department of Interior, 1939:8).

Another significant step towards the development of a tourist industry was the creation of the Organic Act. Passed in 1936 and implemented in 1939, the act resulted in, for the first time, municipal councils elected by the majority of the people. (The wealthy faction still remained in control however, as it took money and time to be elected into office.) The legislative actions reported in the annual report for 1939 noted:

> "Under a law passed by the municipality of St. Thomas and St. John, there was created a 'Virgin Islands Board of Business and Tourist Development' which is assisting in the development and administration of plans to increase and improve facilities." (Department of Interior, 1940:10).

As a measure of importance to the local council, this corporation was developed and approved by the council while such issues as the elimination of privies and the 'night soil service', an ordinance to quarantine the entry to the municipality of people with dangerous, communicable diseases, and the creation of a municipal housing authority to undertake slum clearance (despite the fact that the federal government would be providing total funding) were left unresolved. The municipal council had made its priorities clear. (Department of Interior, 1940:10).

The federal government policy in funding and supporting development programs was guided by the advisory efforts of the municipal councils. Those councils were representative of the successful minority, and the continued emphasis on the development of the tourist trade held financial priority over such things as the health and welfare of the general populace. That the long range planning was successful is evident today, but the same

costs are also evident. Unemployment, housing and food shortages have been a consistent problem throughout the U.S. possession, and yet considerations such as road improvements have had higher priority in the annual budget. The 1938 annual Governor's report stated:

> "In St. Thomas the program (roads) is intimately concerned with the development of this island as a tourist center. Already the improvement of certain roads has led to the purchase of land hitherto inaccessible areas by those who are interested in constructing residences for their own use or for rental to winter residents."

The tourist trade saw a substantial increase in the years before the war, with a number of cruise ships calling in the summer of 1939, several shops were established to cater to the tourist trade.

In 1944, the Committee on Insular Affairs report stated the U.S. intent to assist in the internal development of the Virgin Islands. Recommended improvements were hospitals, sanitary, water-supplies, roads and streets, and recreational facilities...

> "once these have been completed the economy of the Virgin Islands will be benefitted greatly through increased tourist trade because of the attraction of the natural beauty of the islands and the mild weather there..." (HR1673[78-2]).

The logic was sound. What better way to improve the economy and create a self-supporting territory than to plan for, support and stimulate the development of an industry. The problem with the tourist trade is that only a few people really profitted. The majority of the people received very little share of the prosperity, other than sharing a physically deteriorated environment. In 1954, it was estimated that forty percent of the land in St. Thomas was owned by 12 individual firms or heirs; the other major land owner was the government. Despite the efforts of the Homestead Act and the New Deal, the redistribution of wealth in St. Thomas did not occur. By the time of the beginning of the recognized period of

tourist development (1950's) the land, business, government policy, planning and law making had long been in the hands of a very small minority. The physical effects of the tourist industry were not seen until the 1950's, but the socio/political and economic ground work had long been laid.

8.5: 1950's--PRESENT

In 1956, the February issue of National Geographic featured a two page aerial photo of Charlotte Amalie and a large part of the island of St. Thomas. The blue waters of the harbor were offset by the crests of hills, bare of houses. Dirt roads climb the hillside. The only "new" thing observed is the Virgin Islands Hotel. To build this hotel the broad beach at Brewers Bay, two miles from the site, was stripped of its sand. As O'Neill noted: "Development, Virgin Islands style, had begun." (1972:60).

The 1950's and 1960's were marked by a dramatic population growth and economic prosperity, attributed to the "rapid development" of the tourist industry. (See figure 27). Land values in St. Thomas increased from $10.00 per acre in the early 1950's to $25-40,000 in 1969 for half-acre sites. There were no restraints to growth, the lawmakers themselves being the few who prospered greatly. O'Neill summarized the development period as "an orgy of myopic moneymaking." A statement in his book about that period by a former island resident puts the situation in more detailed terms:

> "If I were writing a book of the island in those days I would call it 'the $100 million mistake', because that's how much money which should have gone into schools, and hospitals, and roads, and social services, and in building things for the people of the islands, just disappeared. Don't ask me where it went. I don't know. But it went out there by the suitcase full." (1972:75).

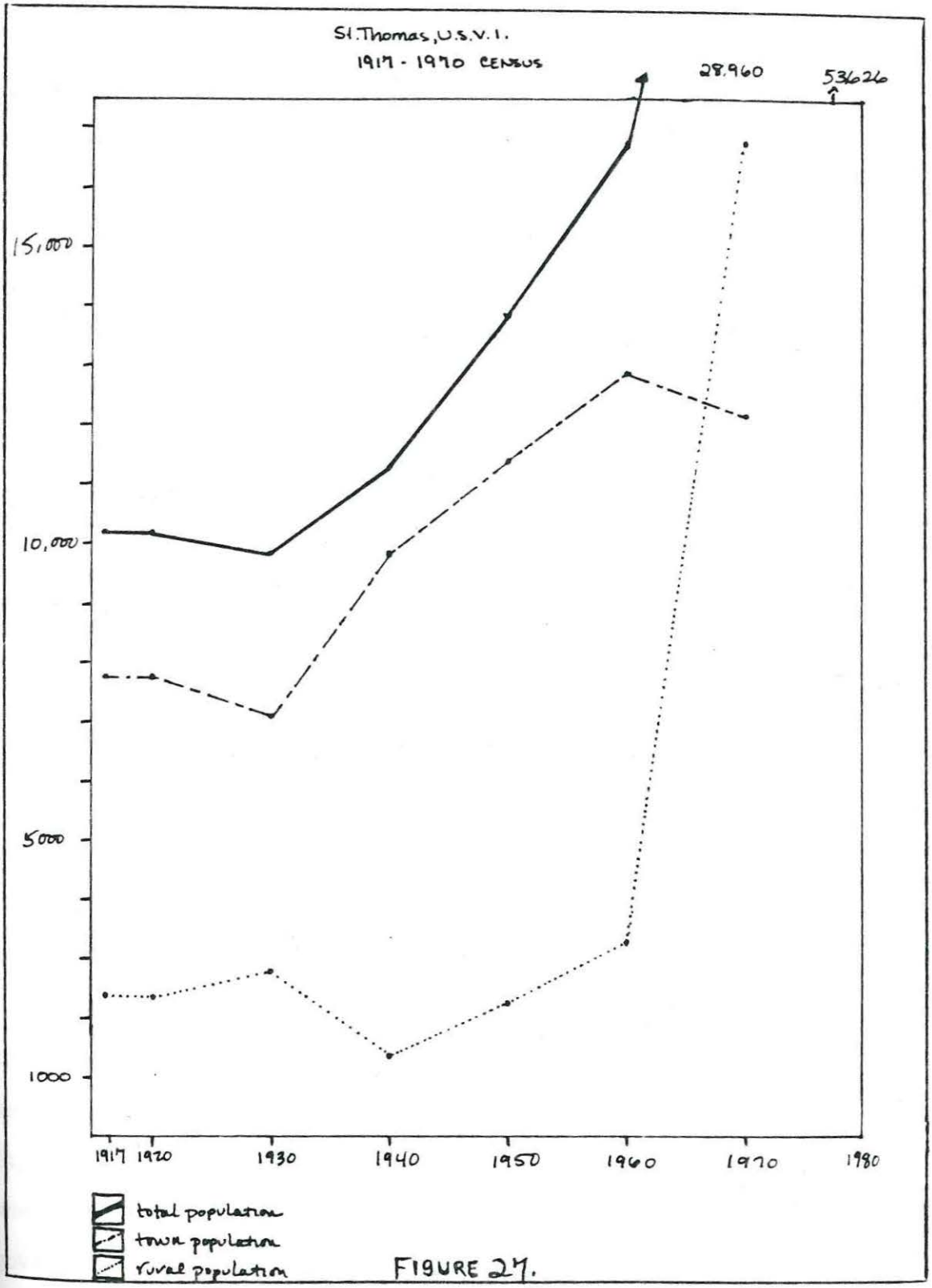

St. Thomas, U.S.V.I.
1917 - 1970 CENSUS
28,960
53,626
15,000
10,000
5000
1000
1917
1920
1930
1940
1950
1960
1970
1980
total population
town population
rural population

FIGURE 27.

In 1961, Ralph Paiewonsky was sworn in as governor and the federal role in the Virgin Islands made advisory. The reorganization of the Organic Act had been passed in 1936, and the powers of the local government increased greatly. The federal government, in addition to the 1917 treaty agreement that returned all taxes collected in the islands to the local government, enacted an agreement where by all excise taxes collected on Virgin Islands products sold stateside would be returned to the local territorial government. Between 1963 and 1969, there was a 520% increase in governmental revenues, of which only a little more than 25% came from sources used by state governments (property taxes, for instance). In the eight years that Paiewonsky was governor one half billion dollars flowed into the territorial treasury, and one half billion was spent.

Improvement was not made in terms of roads, schools, housing, and sewage treatment. The emphasis was on supplicating the tourist industry and few barriers were placed in the way of developers. Beaches and protected bays were soon closed to the public, monopolized by the private hotels and condominium developments. By the end of the 1960's there were only three beaches that were open to the native inhabitants. And growth in the rural areas had increased ten-fold. Yet, little of the new housing was for natives.

The government had failed to provide the Virgin Islanders with decent schooling, adequate housing, good health facilities, and a protected environment; however, the one thing the government did do with its burst of prosperity was to provide the native with a government job. (O'Neill, 1972:36-37). When Paiewonsky took office in 1961 there were 2700 people working for the government. When he left eight years later there were 7100 employed by

the government. An instant middle class had been created by putting the island's natives on the payroll, a payroll that ate up two thirds of the government's operating expenses. (O'Neill, 1972:88).

While the tourist industry brings the most money to St. Thomas, it can be said that the number one industry in terms of employment is the government. A 1975 study conducted by the Economic Development Department estimated that tourism contributes between 33 to 50% of the Territory's gross domestic product. In the Federal Maritime Commission publication "Virgin Islands Trade Study: An Economic Analysis", it was shown that the local government accounts for 35% of all nonagricultural wage and salary employment. The federal and territorial governments together employed a total of 12,820 persons in 1978, 37.1% of the total work force. In comparison, the tourist industry directly employs approximately 20%. (1979, II:44).

The pattern set by Paiewonsky in the 1960's has yet to be broken. With the growth of the tourist industry, the island has prospered. Catering to the millions of visitors who annually vacation in the islands provides employment for a substantial portion of the Territory's work force. An increase in revenues has provided funding for government jobs: the major employer in the islands is the government. A solution to the problem of an impoverished population has been found by putting the populace on the government payroll.

Much of the population of the island is dependent, directly or indirectly, on the continuing prosperity of a tourist-based economy. This dependence has created a fragile economy, where any dislocation in the mainland economy could have serious consequences in the island. An analysis of a tourist-based economy was presented in the 1945 annual governor's report:

"...it is doubtful that the islands can ever become self-supporting on any permanent and sound basis". (1945:2, 16). While the economy of St. Thomas has prospered, it has yet to be seen whether it will achieve a self-supporting status of any "permanent and sound basis".

As the tourist industry developed, so did the island's reliance on outside economies, namely U.S. and Puerto Rico. The majority of food and necessities were now being imported, and outside aid could be depended upon in times of necessity. The federally built government power and desalination plant, as well as daily barges from Puerto Rico, were now supplying water for a population larger than carrying capacity. Improved sanitary conditions decreased the hazards of epidemic diseases. Federal government grants and tax benefits supported the island--even in times of economic decline or natural disasters such as hurricanes. The factors that had effectively regulated population growth in previous years no longer had major impacts on the population: so the population grew.

In 1950, the population of the island was 13,800. A gradual increase in the population level was seen in the next decade due to the building of new roads and the opening of previously inaccessible areas for tourist development. The period between 1960 and 1970 was typified by phenomenal growth, from 16,740 in 1960 to 28,960 in 1970. (U.S. Census Bureau). The impact of the tourist industry finally was felt in St. Thomas as settlement in the rural areas increased 404.1%. (See figure 27). This growth continued in the 1970's, as did the extensive development activities.

St. Thomas is overcrowded. Housing shortages are at a crisis level. The problems associated with population growth were never adequately addressed by the government that engineered the economic activity that stim-

ulated the population growth. The 1977 Housing and Land Use Element estimated that by the year 1979, the population would be 49,784. The 1979 population was 53,626. (Virgin Island Bureau of Vital Statistics).[1] Direct sewage discharge into the harbor and the ocean still occurs, as it has for years. Having too many cars on such a small island has created a twice-daily traffic jam, requiring an hour to an hour-and-a-half to drive through town. Food shortages are common as the island is totally dependent upon the shipping industry for its supplies. Power and water outages are a regular occurrence; the government-owned WAPA (Water and Power Authority) requires millions of dollars to replace or rebuild faulty or out-dated equipment. The summer of 1980 saw three straight weeks with no power for most of the island. No power includes no running water.

And then there is the problem of water. To quote the Daily News 50th Anniversary Edition:

"WATER: ALWAYS A PROBLEM"

> The many costly plans being undertaken by the Virgin Islands government to provide water for the territory gives an impression that there is absolutely no source available on the islands. But the fact is, years ago water was available on just about every street corner in St. Thomas in the form of artesian wells or natural springs...The government has been paying as much as $9000 daily for water barging from Puerto Rico and plans are in the works for purchasing three desalination plants. (1980:B-8).

1. The figures given in the Land Use and Housing Element differ from that of the U.S. Census Bureau. In 1970 the U.S. Census Bureau published 28,960 as the population of St. Thomas. The Virgin Islands Bureau of Research and Statistics estimated the 1970 population to be 37,285. Using the linear projection model they calculated the 1979 population to be 49,784. The Bureau of Vital Statistics reports that the population of St. Thomas in 1979 was 53,626. The recent 1980 census preliminary figures show a population of 43,828. The underestimation, according to the Virgin Islands Government, is believed to have resulted from population underenumeration in both the alien population and low income groups. However, regardless of the accurate figure of population for St. Thomas, the fact remains that the increasing population was not planned for, and serious social, economic and environmental complications have arisen from this growth.

For an overcrowded island the problem of water availability is crucial, How is it that water was once plentiful and now, in addition to the water produced in a desalination plant, must be barged in daily from Puerto Rico? Is it the effects of overpopulation? Too many people utilizing a limited resource? Was the water really as plentiful as suggested by the Daily News article? Answers to these questions can be found by analyzing the land-use activities of this period and defining the subsequent impacts to the environment.

CHAPTER NINE: LAND-USE/LANDSCAPE CHANGE 1917 - PRESENT

What specific land-use acitivities are responsible for changes in the vegetation that condition changes in the hydrologic cycle? The major forms of land-use are concentrated in two geographical areas: town (urban), and country (rural).

Land-use associated with the town includes residential development, public and government construction (such as office buildings, the sub-base, and the airport) and commercial/industrial development. Land-use in the country is oriented towards agricultural activities such as grazing of livestock and farming. Rural residential development is another land-use activity, as are public works projects such as water catchments and cisterns, roads and sewer lines.

In analyzing the changing land-uses in the town and country, the activities will first be identified, changes delineated, and the resulting impacts to surface cover discussed. In the summary, the cultural and physical variables stimulating the land-use and landscape changes will be presented, the reasons for changing land-use and landscape modification summarized, and the impacts of the process of cultural ecological change in St. Thomas on the hydrologic cycle determined.

9.1: LAND-USE ACTIVITIES

The St. Thomas landscape today is one pockmarked with houses, roads, abandoned water catchments, urban sprawl, and other evidences of human habitation. The island landscape has changed considerably since the 1917 purchase from the Danes. Beaches and waterfronts have disappeared, and an entire bay is being filled in for the extension of the airport. Roads have been carved into the hillsides as almost every inch of previously inacces-

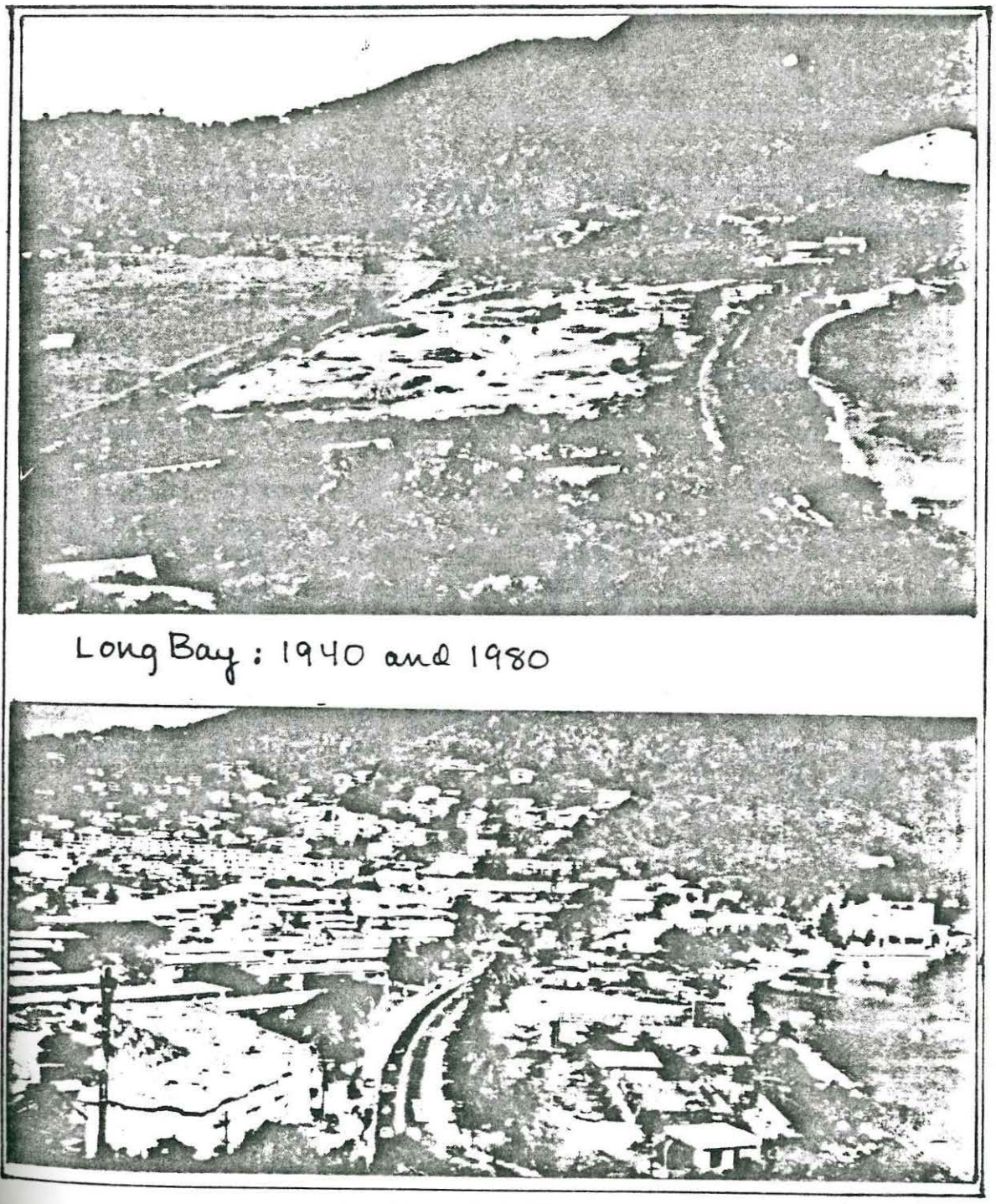
sible land is used for one purpose or another. Entire hills have been graded away. Very few areas can be found today in the same state in which they were when U.S. possession occurred. (See figure 28).

In 1917, the town was concentrated in Crown Bay, and urban land-use activities occurred within the boundaries of the town. The countryside consisted of 10,683 acres, which, for the most part, were used in activities associated with agriculture. Cattle grazing was the dominant form of land-use; in 1926, 80% of the land was reportedly used for livestock. Other activities included deforestation of the countryside for charcoal making and the removal of stones for town construction. The bakery ovens in town were charcoal fired, and continued to be up until the 60's; thus charcoal was constantly in demand. According to one local St. Thomian whose father was a charcoal burner, to make charcoal, certain trees were selected and felled, a pit was dug in the ground, and with herbs and stones to retain the heat, a slow burning fire was built. The pit was covered and the wood smoked for three days, after which the charcoal would be dug up and sold in town.

> "One man would need his land cleared for farming or some such reason, and he would know someone who wanted money. He would say, 'You, take all the stones from my land and sell them in town,' or he would know a charcoal burner and he would let him take all the wood from his land."

The man's land would be cleared for free, and people would earn money as well. (Ethnographic field notes, November, 1980).

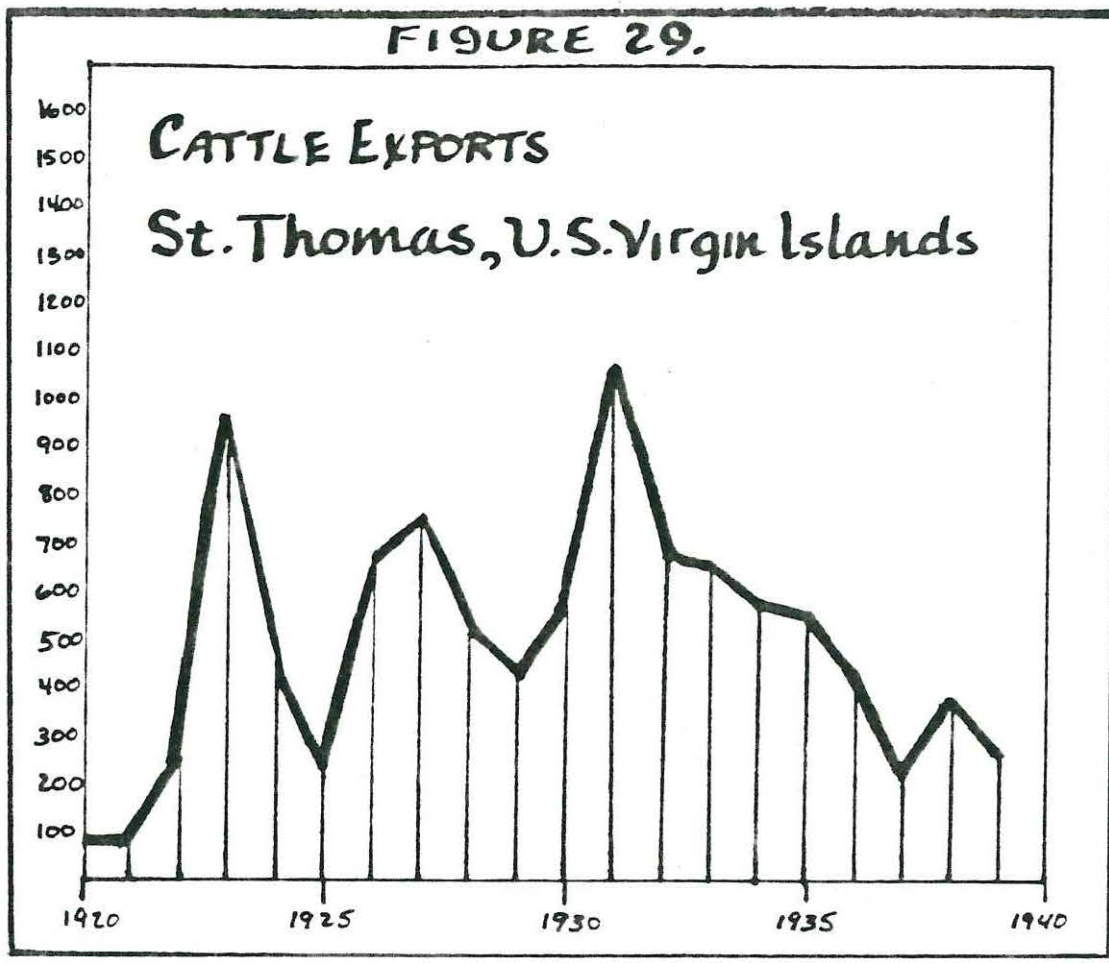
Throughout the naval period, land-use activity remained relatively constant, with only cattle and livestock grazing experiencing growth due to the federal support of marketing in Puerto Rico. (See figure 29). One form of land-use new to St. Thomas was instituted in 1926 when the government constructed water catchments on the hillside above Frenchtown. A large area on



Long Bay: 1940 and 1980

FIGURE 28.

FIGURE 29.


CATTLE EXPORTS
St. Thomas, U.S. Virgin Islands
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
1920
1925
1930
1935
1940

the side of a hill was paved over, and the entrapped water was piped into a cistern. This was connected to the town water supply system. (Evans, 1945: 269).

The policies of the New Deal period attempted to reintroduce agriculture as an industry in St. Thomas, and for a short time 50 lots of six acres were cultivated. This was shortlived, and acreage reverted to pasture or was abandoned. The agricultural centers in the East End and on the North Side continued to provide the only locally grown produce for the St. Thomas market.

As World War II had a dramatic effect on the population and economy of St. Thomas, so too did it effect land-use. The building of a submarine base, military airstrip and military housing facilities outside of the town boundaries served to provide stimulus for growth between the town and Lindberg Bay. As population increased the need for a dependable water supply grew, and more catchments were built. Out of a total of 16 catchments, 14 provided water for the town. The World War II population growth also served to stimulate agricultural activities in the rural area. Shipping activities had been sharply curtailed during the war; the shortage of food created a profitable agricultural industry. After the war, the family-run operation ceased as the farmers emigrated back to Europe. (Oxholm, 1949:52).

The 1950's marked the beginning of active tourist development as hotels were constructed, attracting tourists and stimulating commercial, industrial and residential growth. This increase in tourist-related development activity resulted in abandonment of the cattle industry, as the more lucrative means of subsistence became rapidly accepted. By 1974, only a few square miles were used for grazing. (Jordan & Cosner, 1974:2). The abandonment

of pasture land and consequent succession of plant growth is of crucial importance to the changes in the water balance of St. Thomas, and will be discussed further in later sections.

As the tourist industry became more important to the local economy, the population grew. Commercial activities were concentrated in the town center, pushing residential use to the town outskirts. Since 1960, there has been a marked increase in rural population, reflecting the development of new residential centers due to public housing, native-owned housing, and upper class housing districts. Agricultural uses such as grazing and cultivation dwindled to 8.1% while open space (mostly former pasture) comprised 52.5% of the island. (See figure 30).

9.2: LANDSCAPE AND HYDROLOGIC CHANGE: THE TOWN

Land-use activity in the town changed as the town grew. Town development occurred as the economy changed, and the economy changed as new land-uses were effected. This cyclic pattern is illustrated throughout St. Thomas' history. When one variable changes, the pattern of life changes, thus stimulating further change in the original variable. Many of the major recent land-use changes in St. Thomas began in the period just before World War II. Economic decline and the need for improved defense facilities had resulted in construction activity outside of the town limits. A subsequent in-fill of residential, industrial and commercial developments led to a doubling of the town's physical size within a seven year period. (Bellini, 1966:54). The building of the St. Thomas Virgin Island Hotel in 1956 further stimulated growth outside of the town limits. As areas outside of town became more and more accessible (through the building of new roads to serve the government, military and tourist facilities) residential growth was

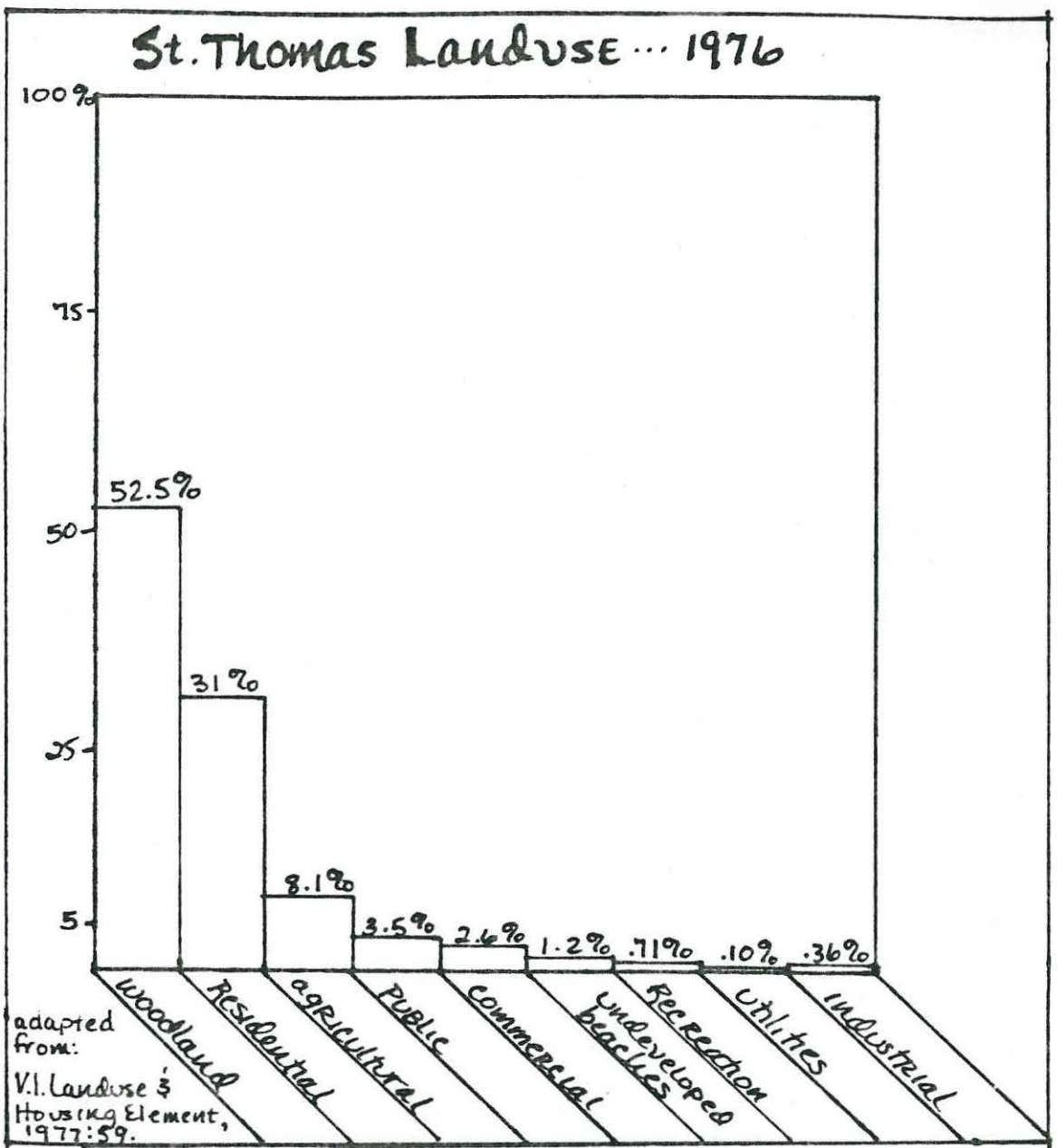

St. Thomas Landuse ... 1976
100%
75
50
25
5
52.5%
31%
8.1%
3.5%
2.6%
1.2%
.71%
.10%
.36%
Woodland
Residential
agricultural
Public
Commercial
Undeveloped beaches
Recreation
Utilities
Industrial
adapted from:
V.I. Landuse & Housing Element, 1977:59.

figure 30.

stimulated. During the 1960's the town grew some 1200 acres east and west of its original boundaries. (Bellini, 1966:54). The character of the town changed from a mixed residential business center serving the local island needs to a commercial district almost totally oriented towards the tourist trade.

The growth of the town has brought an increase in paved surfaces, storm drains, and the changing of, or filling in the natural drainages. Figures 31 and 32 illustrate the natural vegetation and current surface cover. Beach fronts were stripped of their sand for construction needs, water fronts were filled in and marshes drained and filled. An airport was built on what was once marshland, and the impacts to drainage can be seen to the landward side of the strip, where a year round pool of water stands roadside. Sub-base complex was built on "reclaimed" land, and the existing waterfront highway was what used to be mangroves and beach front.

Land-use activity in the town resulted in an impact to the hydrologic cycle, particularly seen in an increase in stormflow and a decrease in the subsurface water table. The guts and springs near town are fed by the watershed surrounding the town, which up until the mid-1950's had been bare of town-associated development. Stormflow was somewhat regulated by the surface cover which was largely pasture. Since the mid-1950's the area has become increasingly developed, roads wind through the contours of the mountains and residences are constructed wherever physical space permits. Drainage has been affected by septic tank seepage and storm flow/sewer pipe construction. Rapid run-off occurs during rain storms, and consequently, there is little discharge during drier seasons. The result is a subsurface aquifer which has little occasion to recharge. While annual

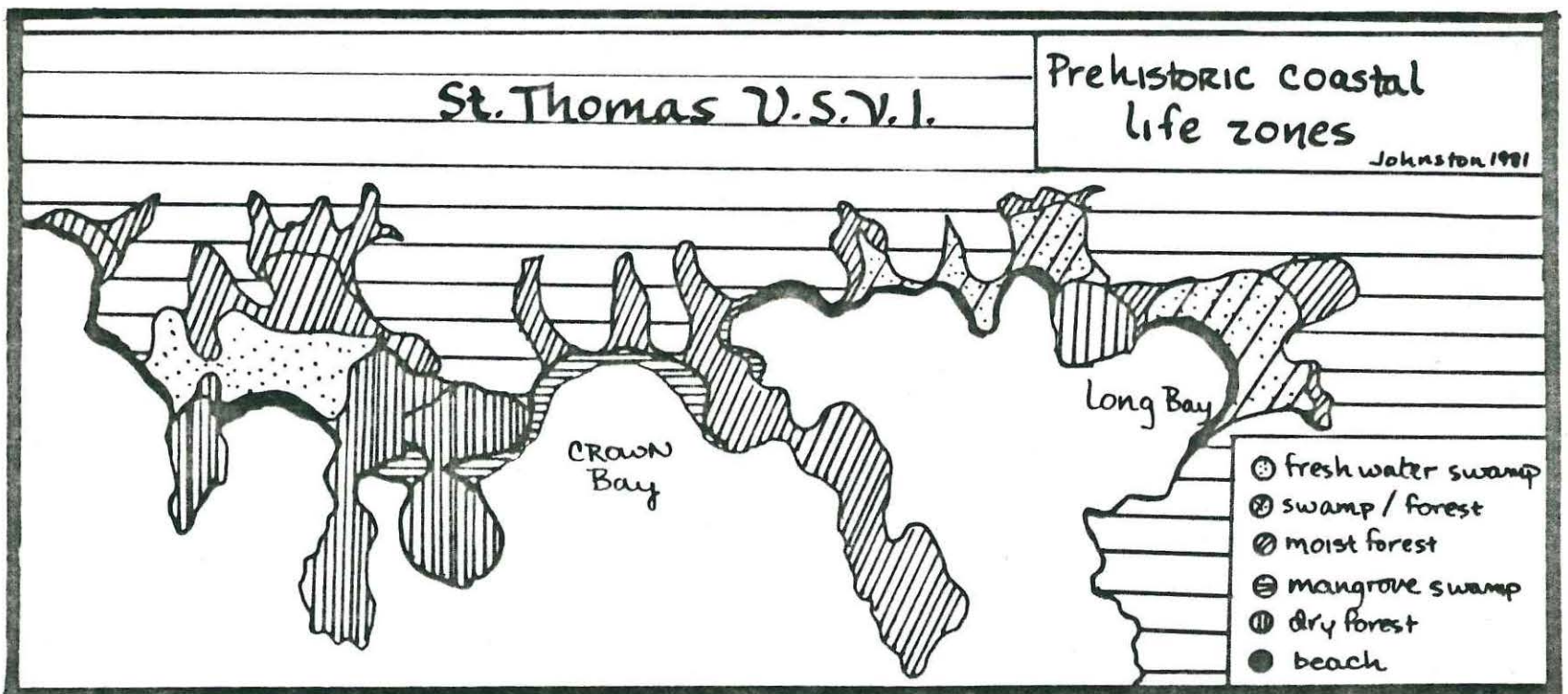

St. Thomas V.S.V.I.
Prehistoric coastal life zones
Johnston 1981
Crown Bay
Long Bay
fresh water swamp
swamp / forest
moist forest
mangrove swamp
dry forest
beach

Figure 31.

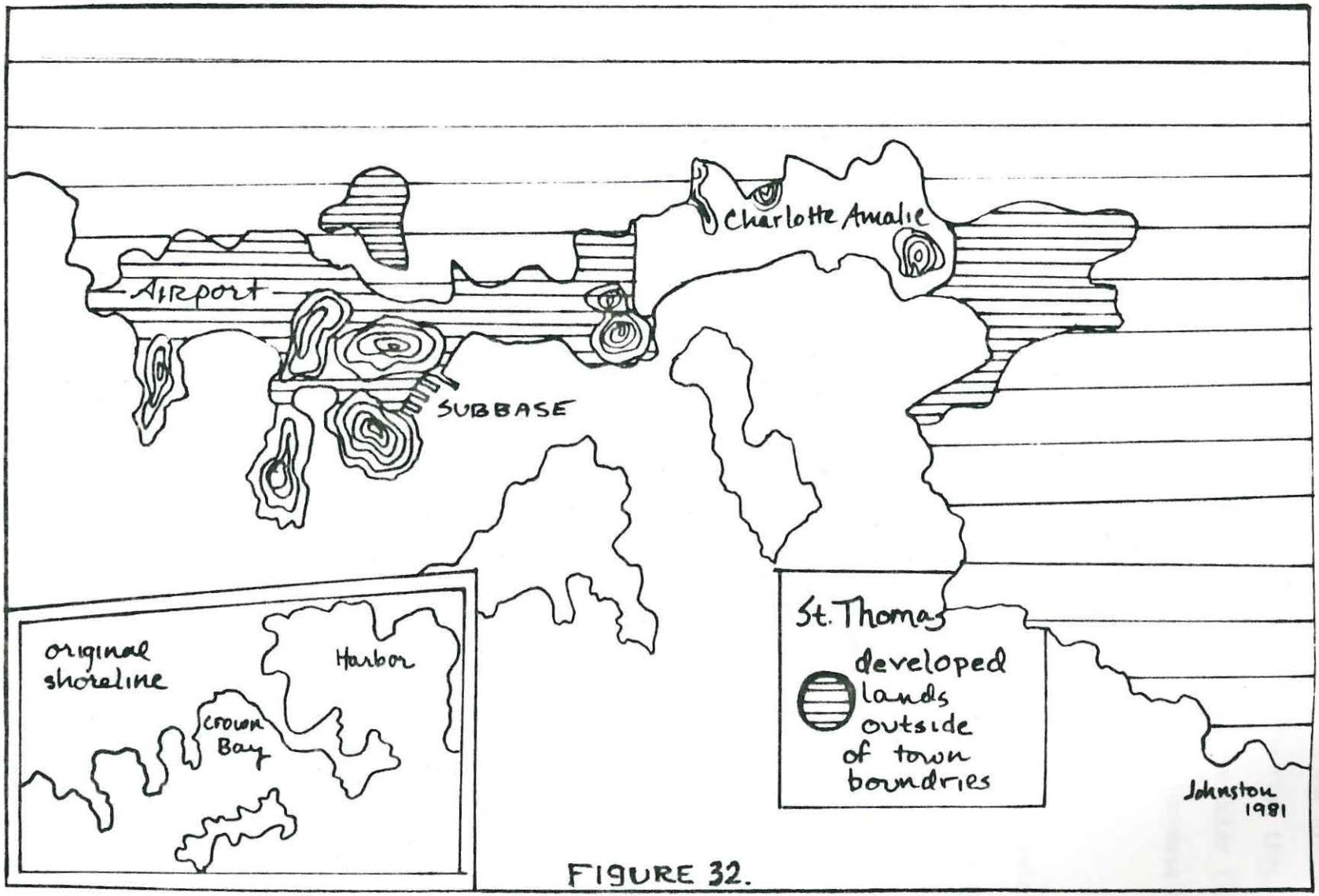

Charlotte Amalie
Airport
SUBBASE
original shoreline
Harbor
Crown Bay
St. Thomas
developed lands outside of town boundries
Johnston 1981

FIGURE 32.

rainfall has declined somewhat, the more important factor in the hydrologic cycle has been the change in which water is utilized, or the flow through the system. In watersheds surrounding the town the changes in water flow are directly related to an urban land-use which stimulates an increase in storm run-off.

9.3: LANDSCAPE AND HYDROLOGIC CHANGE: THE COUNTRY

In 1917, when the major form of surface cover was pasture, a relatively high proportion of water was able to seep into the soil and gravitate downwards to the subsurface aquifer. The development of the countryside changed the amounts of water that went into run-off, soil moisture, recharge of the aquifer, stream flow and evapotranspiration. As the number of livestock using the land increased, overgrazing occurred with subsequent deterioration of the soil structure and vegetation, stimulating an increase in run-off. The drought of 1923-1924 was most probably influenced by two factors: a decline in the annual rainfall; and a change in the ability of the soil to store moisture due to the impact of overgrazing. In later years this intensive livestock use declined. A large number of stock died during the drought and the federal controls concerning livestock with bovine tuberculosis disease restricted the marketing of cattle in the Puerto Rican market. Disease eradication efforts of the federal government consisting of dipping the livestock bi-monthly for an 18 month period allowed the resumption of trade, but the St. Thomian industry never again reached the heights it had experienced in 1931. (Department of Interior, 1931:7). Pasture lands continued to be a dominant form of the landscape until 1950. The eight dairy farms in 1936, decreased in number to four dairy farms in 1957, three in 1960, and one dairy farm in 1980.

The rural landscape has changed from a predominantly agricultural use to mixed residential/industrial and open space. Very little acreage remains today in agricultural use. The results of these land-use changes are especially evident when looking at the changes in vegetation.

As described earlier, the original landscape of St. Thomas was largely forest. Colonizing efforts in early historic times resulted in a rapid deforestation of the island. (The usual procedure was to set the area on fire.) St. Croix reportedly burned for two months. (Knox, 1852:159). The aftereffects of firing result in a mineral-rich soil, and cultivation efforts on St. Thomas were largely successful in the early plantation years. However, continued cultivation efforts resulted in a draining of the soil of its nutrient contents, and when cultivation efforts were abandoned in many areas, the more mesic forests were unable to return. First stage succession in a previously cultivated area is the scrub-grassland formation. Through livestock grazing and occasional planting of grasses, a surface cover of pasture was maintained for many years. While not as effective as the original forest cover in maintaining the water balance, the grassland did enhance the soil's capacity to absorb moisture. Thus, little change in the hydrologic cycle was perceived while the pastures were maintained. However, once conditions were allowed to deteriorate, either through overgrazing or abandonment and subsequent regrowth of the thorn-scrub woodland, the hydrologic balance changed. The areas influenced, and the severity of change in the water flow were minimal and temporary during the historic period, when drought conditions had a severe effect on the local economy. When an overuse occurred and a drought was perceived, there were subsequent changes in the land-use, due to loss of livestock or crops, abandonment of land, migra-

tion, et cetera. This allowed fluctuations to become temporary, and in a few years the cycle would return to its original balance. A more damaging change in the hydrologic balance occurred when the widespread land-use of livestock grazing was rapidly and almost completely abandoned. Open space succession occurred in the form of thorn-scrub woodland, as the long term misuse of the land had created soil fertility and water availability conditions no longer sufficient to support the original moist or wet forest associations. The ability of the thorn-scrub woodland to tap deeper sources of water resulted in a 3-5% increase in evapotranspiration. (Peebles et al, 1979:10) and a decrease in the off-season stream flow. Run-off rates increased as the vegetation supported a less dense ground cover.

One annual stream is found on the island, Turpentine Run on the East End. Immediately outside of the drainage is a zone of xeromorphic vegetation. The original dry forest boundaries have shifted, as land-use activities have created conditions tolerable to only the more xerophytic associations. This extension of the dry forest is evident when looking at Zube's map of Terrestrial Vegetation Zones. (See figure 7). Based upon the existing vegetation the map shows a large portion of the island as covered by dry forest associations. Whether this condition is temporary or permanent is debatable, and can only be seen through the passage of time. However, there is an example on the Northside of the island of long-term abandonment, and the current vegetation reflects a more mesic oriented succession.

Neltjeberg Estate was purchased in the 1850's by Jacob Roger Maalenaar (Moolenaar), and the existing sugar factory was converted into a residence. The estate was then used for dairy farming. Cattle were grazed on the crown of Ruy Point. In 1867, a hurricane struck St. Thomas, destroying the estate

structures, and the site was abandoned. As access to the area was limited to a steep road (now reclaimed through vegetation growth), a seaward approach, or climbing the point from Dorothea Bay, the area has remained relatively undisturbed for the past 100 years.

The point was purchased by the Territorial Government for future parkland, and the remainder of the estate is still in the hands of the Moolenaar family. The area was surveyed and a park development plan written in 1976 by Timothy B. Still for the Department of Conservation and Cultural Affairs, Office of Planning and Development, U.S. Virgin Islands Territorial Government. This report has been filed, and no development activity has occurred since governmental purchase.

In Still's report he notes that the vegetation along the shore consists of a variety of cacti and typical Virgin Island salt-resistant plants.

> "The crown of the point was used at one time for running cattle, and is now covered with a secondary growth arid forest complex. At the North, this consists of a palm forest which provides a shady canopy, while more typical cassia/maran scrub lies to the South." (1976:2). (See figure 33).

The area was again surveyed in January of 1981, by the Office of Archeological Services. In addition to the historic and prehistoric resources, the field report gives the following descriptive account of the vegetation:

> "In climbing the hillside from Dorothea Bay to the top of the point the vegetation is typical of coastal-thorn scrub. Once the crown is reached however, there is a distinct change in the vegetation. The canopy is much higher, and the ground cover more bare. Cactus sp. are still found, but the predominant form of vegetation is the fan palm, which is at least 20' in height. Some vines are found, mostly with thorns. With the descent into Neltjeberg Bay there is again the thorn scrub woodland, but as the slope is not as steep, this transition is more gradual. Once the floor is reached the vegetation resembles the north-side forests, with a high canopy, some epiphytes, and limited ground cover in the forests. Herbacious species are found in the clearings." (Johnston, 1981:5). (See figure 34).

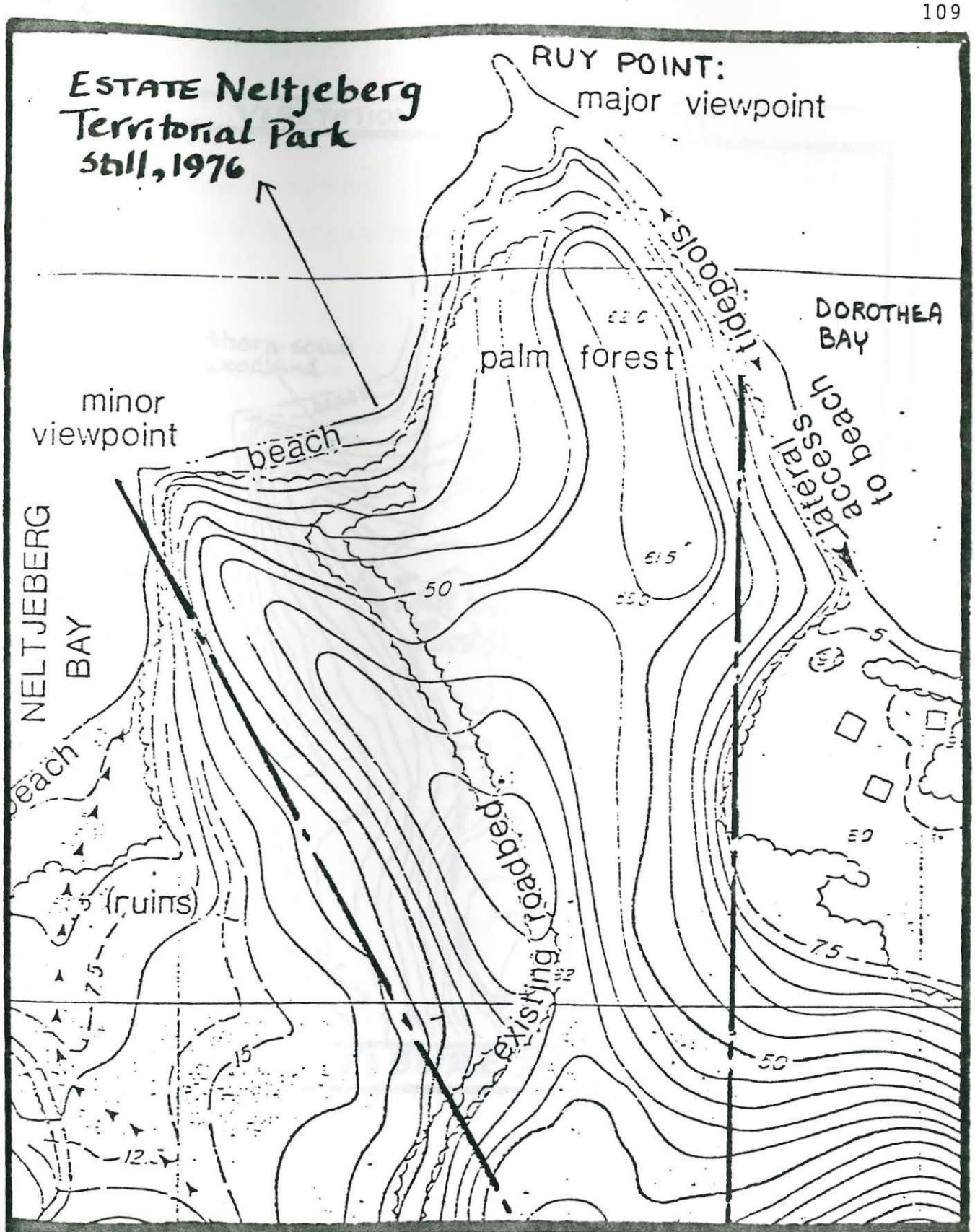

ESTATE Neltjeberg
Territorial Park
Still, 1976
RUY POINT:
major viewpoint
tidepools
DOROTHEA
BAY
palm forest
minor
viewpoint
beach
lateral access
to beach
NELTJEBERG
BAY
beach
(ruins)
existing roadbed
50
75
15
12
5

FIGURE 33.

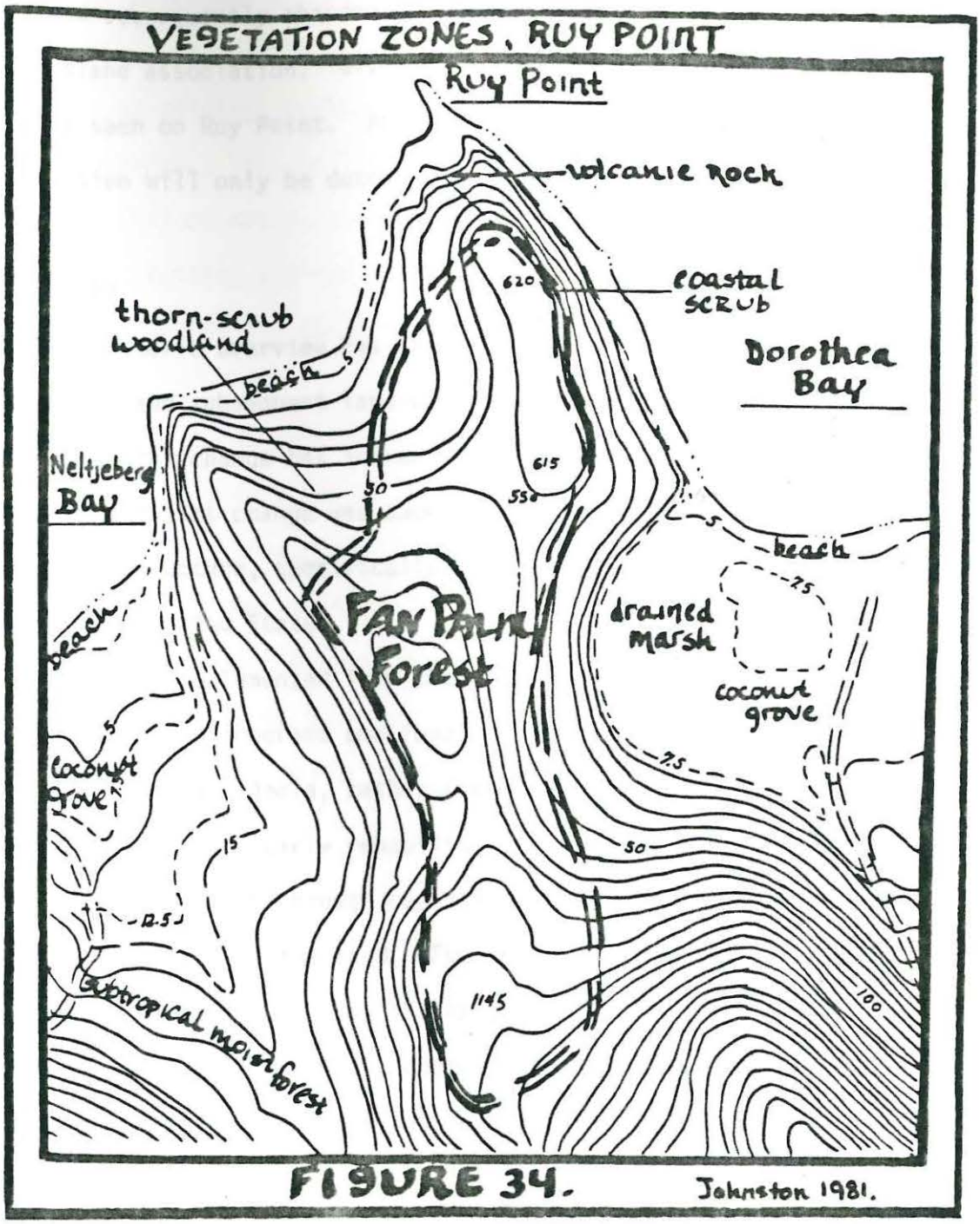


FIGURE 34. Johnston 1981.

Other areas on that same side of the island have been used for cattle grazing and subsequently abandoned. Regrowth is in the form of the thorn-scrub woodland association. Given time, perhaps the more mesic forest will succeed as seen on Ruy Point. As previously stated, the eventual form of the succession will only be determined with finality through the passage of time.

9.4: SUMMARY

This historic overview has served to illustrate changes in socio/economic structure and subsequent land-use in St. Thomas. The pace of cultural and environmental change has increased rapidly since the turn of the century, and impetus for that change was supplied through a change in the political and economic structure, specifically, through the purchase of the Virgin Islands by the United States.

The policy implemented from the start was the Americanization of the people. Government programs and fundings were oriented towards achieving the traditional American ideals, rather than reflecting the West Indian lifestyles. One major fault of the early rehabilitation programs was the attempt to encourage economic growth through capitalistic enterprises without accomplishing a redistribution of the land. From early on, the only people who really gained in the economic policies of the government were the small minority of land and business owners. Thus, control of the economy and the planning for future direction of the economy was, and for the most part still is, in the hands of the wealthy.

When economic prosperity was derived from agriculture, the dominant form of land-use was plantations owned by a small percent of the population. Later, economic prosperity was supported through shipping and trading, and

the concentration of economic activity was around the harbor. The enterprises and establishments that employed the majority of the people were, again, owned by very few people. As time passed and economic prosperity could be had by raising cattle to feed the shipping industry, and later, the Puerto Rican market, the small number of landowners converted their estates to pasture. Most recently, when tourism developed, and was supported by U.S. policies, funding and tax programs, and U.S. tourists, the people who prospered were again, the small minority who owned the estates and businesses in town.

The attempt by Paiewonsky in the 1960's to raise the overall standard of living, succeeded to a point. An instant middle class had been created through the swelling of government ranks. But the cost of living in the Virgin Islands is higher than any place else in the U.S., including Hawaii and Alaska, and the existence of the new middle class is dependent upon the continuing support of the local government, which is dependent upon the tourist industry for revenues. Again, the only group who have really prospered are the employers and landowners rather than the employees. In 1949, the lower half of income recipients received about 5% of the total income for that year; by 1959 the percentage had risen to 13% and in 1970, the lower half received approximately 16% of the total income earned in that year. (The Significance of Tourism in the U.S. Virgin Islands, 1973:33).

The current economic status has been achieved and is maintained because it is profitable to the upper class. Despite the fluctuations in the economy the social problems of the island have remained constant throughout the American period. It was noted in a 1949 report that the islanders were spending large sums of money for food and provisions, while tracts of culti-

vateable lands lie fallow. This had been noted in a 1919 report, and again in a 1979 report. (Oxholm, 1949:35; SR160[66-1]; Virgin Islands Trade Study, 1979:II;47). Until a redistribution of land is achieved, or until it becomes profitable to do so, agricultural land will continue to lie fallow or be swallowed up through the current trend of urban sprawl.

CHAPTER TEN: THESIS CONCLUSION

The relationship between economic change, land-use and landscape change has resulted in detrimental effects on the physical environment of St. Thomas. Without conscientious island-wide constraints, environmental deterioration will continue.

This study of the water problem has served to illustrate two major lessons. First, hydrologic changes will be closely related to vegetation changes. This relationship is extremely important in the island ecosystem, where the availability of water is limited to what falls from the atmosphere. Second, land-use practices can have significant effects on the availability of water. The occurrence of drought is, in this case, a cultural perception. The incoming flow of water has changed relatively little; instead, what has changed is the way in which water flows through the system, and this is a direct result of cultural intervention.

In St. Thomas, changes in the political and economic structure from a local-based economy to one strongly dependent upon the U.S. mainland, were reflected in changes in land-use. That change in land-use resulted in a change in surface cover, which affected the evapotranspiration rate and caused a decrease in water availability. Thus, the natural hydrologic cycle was modified. As the pace of culture change on St. Thomas had increased, feedback mechanisms were rendered inoperative, and the culture failed to recognize the disturbance in the ecosystem.

When the problem of water was realized, the measures taken were oriented toward introducing additional water into the system; the symptoms were treated rather than the problem. A desalination plant was built and water was regularly shipped from Puerto Rico. Rather than focusing on how the problem of

water availability occurred and how to rectify that problem, the federal and local government concentrated its energy on solving the immediate water needs. As a result, the local economy had further strengthened its ties to a foreign economy as a means of subsistence. Thus, the inability to perceive or rectify the problem of a deteriorating ecosystem has resulted in a hydrologic crisis.

In St. Thomas, as in many Caribbean islands, the largest portion of the land is currently abandoned pasture or cropland. The successional stage is relatively new, and the dominant species are of the pioneering type found in thorn-scrub woodland and other dry forest associations. Long-term abandonment may result in more mesic conditions, as illustrated at Neltjeberg Bay and Ruy Point, and a re-establishment of the natural hydrologic cycle is a possibility. Whether or not this will occur depends upon the continuing lack of human disturbance.

If recent development trends are indicative of the future, few areas will escape residential, commercial, and recreational development stimulated by the tourist industry. This is rapidly becoming a reality for not only St. Thomas, but most of the Caribbean islands as well. Can the problem of water be solved while the tourist-based economy prospers? One possibility is through a combined effort of reforestation and planned growth, with an awareness of the physical limits to growth.

On islands such as St. Thomas, it is entirely possible that the limits to growth have long since been overreached. The continuing development is dependent upon the prosperity of the government, which is in turn catering to a tourist-based economy. A re-evaluation of government financial priorities should occur, stressing the self-sufficiency of the island rather than

the dependency upon a foreign economy. Historically, critical issues such as water, food, and housing have been avoided, at least to the point that these problems have never been solved. It is suggested that the current environmental problems will not be alleviated until the political and economic structure is localized and simplified.

As the physical environment is directly related to land-use practices, and these practices are representative of the local economy (which in turn is dependent upon a foreign economy), changes in the local economy are necessary to effect a positive change in the cultural and physical ecosystem. It is doubtful that such a change will occur in the near future, unless the recent decline in tourism and cutback of federal support continues. As the economy is built upon the tourist industry, and the majority of employed persons work for the government, any change in the economy will have a rapid and direct effect on the populace. The political and economic structure will be forced, through these external pressures to become localized and simplified.

In the preface of this thesis, it was stated that one of the reasons for doing this study is to provide a picture of St. Thomas that, in turn, reflects a possible future for the Caribbean as a whole. Many islands have problems similar to St. Thomas, having a like history of colonization, plantation, abandonment, and recent growth through the tourist industry. Few islands are, however, as intensively developed and dependent on the tourist industry as St. Thomas. In presenting the process of land-use and landscape change in St. Thomas, it is hoped that other islands, through realistic and visionary planning, can avoid the environmental crisis found on this island today.

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