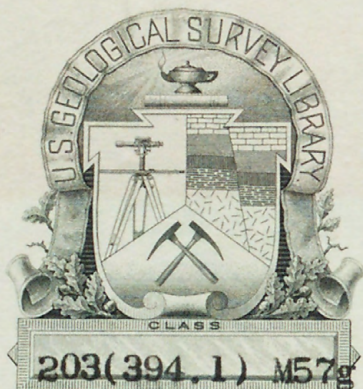


Geology and Hydrology of
Dam Sites on the Island
of St. Croix, Virgin Islands

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGY AND HYDROLOGY OF DAM SITES

ON THE ISLAND OF ST. CROIX, VIRGIN ISLANDS

By

Rex R. Meyer

Geologist



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ABSTRACT

The Virgin Islands Corporation plans to build a series of small earth dams along some of the streams on the island of St. Croix, and field studies involving the selection and hydrology of possible sites was carried on by the Geological Survey during the months of August and September 1951. The island of St. Croix is the largest of the three principal islands of the Virgin Islands group owned by the United States. It is about 21 miles long and 6 miles wide near the center and has an area of about 84 square miles. The northwestern part of the island contains mountains that reach a maximum altitude of 1,165 feet; the eastern half of the island is submountainous, containing some hills 600 to 800 feet in altitude. A coastal lowland area containing a few east-west-trending marl and limestone hills characterizes the southwestern part of the island. The streams in the east half of the island and along the northwest coast are relatively short and are dry during most of the year. The streams draining the mountains from the south cross the coastal lowland in narrow and shallow ditches. The southeastward drainage from the eastern part of the mountainous area is diverted by Salt River and enters the sea on the north coast of the island. In the headwaters of some streams there is a small flow of water during most of the year that disappears below the surface upstream from or near the foot of the mountains. During most of the year the streams are essentially dry, flowing only after periods of heavy rainfall.

In the coastal lowland near Bethlehem the average annual rainfall is about 46 inches. The east end of the island is relatively dry and the precipitation is estimated to be approximately 20 inches annually; the northwestern end of the island receives the most rainfall, probably more

than 50 inches annually. Records show that from 1861 to 1876 there was deficient rainfall and the accumulated departure below normal was about 56 inches (fig. 2). From 1876 to 1920 there were numerous years of above - normal precipitation and the departure curve rose nearly 100 inches, to more than 40 inches above normal. From 1936 to 1950 there has been a more or less continuous decline in rainfall, amounting to a net deficiency of 72 inches, or from 44 inches above to 28 inches below normal. These changes in rainfall have a direct effect on the volume of stream flow on the island.

There are two general rock types on the island. The Mount Eagle volcanics and the intruded diorite are hard, dense crystalline rocks; the rocks underlying the coastal lowland and belt of hills between Salt River and Christiansted are sedimentary rocks, such as marl, limestone, sand, gravel, and clay. The permeability of the crystalline rocks and of the gray clay and basal conglomerate of the Jealousy formation is low and they are water bearing in few places. The Kingshill formation is composed of light-gray clay and light-yellow marl and included beds of limestone. In places the limestone contains solutional openings that yield water to wells. The alluvial sand, gravel, and clay that unconformably overlie the Kingshill marl include permeable beds that yield relatively large quantities of water to wells in a few places.

It is evident from the small stream flow that by far the greatest part of the 46-inch average annual precipitation on the island is returned to the atmosphere through evaporation and transpiration. There are no records of stream flow or ground-water flow from the drainage basins, but it is estimated that in some years the amount of water lost through evapotranspiration may be more than 90 percent of the total water available. It is proposed that a

program be started and continued to collect and evaluate data on the hydrology of the island.

The purpose of the dam-building program is to retain on the land a part of the water that formerly flowed to the sea and was of no beneficial use. Owing to the lack of hydrologic data, the maximum number of dams needed is not known; consequently, practically all possible sites on publicly owned land and sites that would benefit those lands were studied. Thus, 3 sites were selected in the valley near Little Grange that is a source of supply to the public-supply well field of Frederiksted; 19 sites were selected on or near property owned by the Virgin Islands Corporation; and 4 sites were selected along the Salt River above the public-supply well field of Christiansted. During most of the year the water table is at or below the beds of the streams; consequently, if permeable rocks underlie a pond or dam it is possible that there may be leakage from the pond to the water table. In general, leakage from dam sites underlain by crystalline rocks of the Mount Eagle volcanics or clay of the Kingshill marl will be negligible, but leakage from sites underlain by limestone in the Kingshill marl or sand and gravel of the alluvium may be great. Potential leakage at each site selected is discussed.

INTRODUCTION

Purpose and Scope of Investigation

In July 1951 the Geological Survey, United States Department of the Interior, was requested by the Office of Territories of that Department to make a preliminary survey of the sites of dams on the island of St. Croix, Virgin Islands, proposed for construction under an appropriation made to the Virgin Islands Corporation, a governmental agency. The purpose of the investigation was to determine (1) the probable effect of the proposed dams on the water table, (2) potential leakage under or around the proposed dams, and (3) the possibility of recovering the leakage, if any, for beneficial use. During the investigation proposed sites were examined on the streams crossing the property owned by the Virgin Islands Corporation, in the Salt River valley, and in the valley near Little Grange. The Salt River and Little Grange valleys are in the drainage basins supplying the well fields of the towns of Christiansted and Frederiksted, respectively. Twelve test holes were drilled at eight proposed sites to determine the approximate thickness and character of the alluvium. A topographic survey of the two main stream channels crossing the property of the Virgin Islands Corporation is being made by the engineering staffs of the Virgin Islands Corporation and the U. S. Soil Conservation Service. It is anticipated that this map will be completed in the near future.

The investigation was made under the general supervision of A. N. Sayre, Chief of the Ground Water Branch of the Geological Survey.

Location of Area

The island of St. Croix is one of the westernmost islands of the Lesser Antilles. It is about 95 miles southeast of the city of San Juan, Puerto Rico, and about 1,130 miles southeast of the southern tip of Florida. The island is between latitudes $17^{\circ}41'$ and $17^{\circ}48'$ north and longitudes $64^{\circ}34'$ and $64^{\circ}54'$ west. St. Croix is the southernmost and largest of the three principal islands (St. Croix, St. Thomas, and St. John) of the Virgin Islands group owned by the United States. The island has a maximum width of 6 miles near the center, is about 21 miles long, and has an area of 84 square miles. The islands of St. Thomas and St. John are about 40 miles north of St. Croix and have areas of 28 and 20 square miles, respectively.

Acknowledgments

The field work was greatly facilitated by the cooperation given by the Virgin Islands Corporation, the Soil Conservation Service of the Department of Agriculture, and the Office of Territories. Francisco Colón Moret, who at the time of the field study was Plantation and Mill Manager of the Virgin Islands Corporation, obtained the necessary equipment and personnel for drilling test holes and supplied much valuable information on the existing dams on the property of the Virgin Islands Corporation.

GEOGRAPHY

Physical Features

The western half of the island of St. Croix is 5 to 6 miles wide and approximately rectangular in shape. The northwestern part of the island is mountainous; to the south, a relatively flat lying lowland extends from the flanks of the mountains to the south coast. The mountainous area ranges in width from about 3 miles near Frederiksted to about $1\frac{1}{2}$ miles near the Salt River. Mount Eagle and Blue Mountain are the highest mountains on the island and are 1,165 and 1,090 feet in altitude, respectively. The streams in the northwestern part of the island, as well as on the rest of the island, are all intermittent and flow only during periods of heavy rainfall. The Salt River valley is the only valley having a relatively large drainage area that reaches the sea along the north coast. Salt River enters the sea at Sugar Bay, which is at about the midpoint of the island, immediately east of the mountainous area. The south side of the mountainous area from Sugar Bay to Mount Eagle is drained by streams whose headwaters flow southeast but which are diverted northward by the Salt River. Along the northwest coast of the island the stream valleys are short, generally draining areas extending less than a mile inland from the coast. When the area was first visited during August 1951 there was no flow in any of the streams in the Salt River drainage area or in the short valleys along the north coast.

Along the west coast of the island from Frederiksted to Ham Bluff there are a number of stream valleys up to 3 or 4 miles long. Caledonia

valley and the valley extending east of Sprat Hall are deeply incised and extend eastward about 2 miles. When visited, these streams had a small flow, about 1 to 5 gallons a minute, in their upper reaches but were completely dry in the lower reaches. The valley near Little Grange and Jolly Hill is about 4 miles long. In the mountainous area the valley is deeply incised; however, it crosses coastal lowland deposits from a point about 0.7 mile from the coast, and from this point it gradually decreases in depth and width so that it is a ditch only a few feet deep and wide where it meets the sea. No flow was observed in the channel of this valley in August 1951.

A coastal lowland extends from Frederiksted in the southwestern part of the island to a point near Spring Bay in the south-central part of the island. This lowland is a relatively flat plain that slopes to the south and contains a few low east-west-trending hills of marl and limestone. The lowland reaches its maximum width of about 3 miles just north of Bethlehem. Most of the streams draining the south side of the mountainous area extend relatively short distances into the mountains, and where they enter the coastal lowland they form relatively shallow ditches or, as they are called locally, guts. The largest drainage basin on the island, about 10 square miles or 6,400 acres, extends northward across the plain in the vicinity of Bethlehem and into the mountains to within about half a mile of the north coast. At Fair Plain the stream branches into two separate

valleys, the west branch extending to near Fountain and the east branch to near Solitude. These two main streams have not been named and for convenience they will be referred to in this report as the East Branch and West Branch. Between Fountain and River the valley of the West Branch is underlain by diorite. As the diorite is more easily weathered than the adjacent volcanic rocks, the valley is broad and the gradient is not as steep as those of the other streams in the mountainous area. The drainage divide of the West Branch is north of Fountain and within half a mile of the north coast of the island. From River to Fair Plain the valley of the West Branch is a shallow entrenched ditch generally not more than 100 feet wide or 20 feet deep. Between Solitude and Colquhoun the valley of the East Branch also is underlain by diorite and the basinlike head of the valley is about a mile from the north coast of the island. The course of the valley across the coastal lowland, except in the lower reaches, is about parallel to that of the West Branch. The flow of both branches is intermittent. During the dry season some parts of the upper reaches of the West Branch have a small flow; for example, during August 1951 there was a flow of about 5 gallons a minute past the small dam near River, which disappeared a short distance downstream. Except for the small amount of water impounded by the existing dams and in a few small pools, the channels of these streams in the lowland area have no flow during dry weather. The main flow of these streams generally occurs in September, October, and November, the months of the highest rainfall. It is

reported that water flows down these streams for several days after a prolonged period of rainfall. The character of the runoff is shown by the shape of the valleys, particularly in the West Branch between Golden Grove and Fair Plain; here the stream has cut a U-shaped valley about 15 to 20 feet deep; the small tributary valleys have not had a great-enough flow to keep pace with the erosion in the main valley and thus have formed miniature hanging valleys. The shape of the valleys, therefore, shows that the flow of the streams has been intermittent and flashy.

From the hills east of the Salt River valley to Christiansted a lowland about half a mile wide extends along the north coast. South of this narrow lowland is a belt of limestone and marl hills which have a maximum altitude of about 500 feet. East of Christiansted there is no continuous coastal lowland, and hills, ranging in altitude from 845 feet near Christiansted to 660 feet near the east end of the island, extend to the coast. Between Southgate Pond on the north coast and Great Pond on the south, a shallow, saddle-shaped valley has been formed across the island in an area underlain by diorite. This valley is from half a mile to a mile wide, and the divide is at an altitude of about 150 feet. The streams in the eastern part of the island are short and intermittent and some valleys are about as wide as they are long.

Climate

An official weather station of the U. S. Weather Bureau was established at Alexander Hamilton Field, west of Fair Plain, in June 1947. The 3-year record obtained at that station shows the annual average temperature on St. Croix to be 79.1 degrees. For the period of record the extremes in temperature are 63 degrees and 94 degrees. December is the coolest month of the year, with an average temperature of 75.7 degrees, and July and August are the warmest months of the year, with an average temperature of slightly more than 82 degrees.

The humidity is highest in October and November, when it averages 88 percent at night and 77 percent during the day. The lowest humidities are generally in March and April, averaging 82 percent at night and 69 percent during the day.

The annual prevailing wind varies from east-northeast to east-southeast and averages 12.2 miles per hour. The tropical hurricane season is from June 1 to November 1 but, although the weather on the island is affected several times each season by the nearby passage of these disturbances, the island has not had a wind of hurricane force since the establishment of the U. S. Weather Bureau Station in 1947.

Although adequate records are not available, it is evident that there is a great difference in the annual rainfall throughout the island of St. Croix. The easterly winds carry the clouds across the island from east to west and, as the highest mountains are in the northwest, most of the precipitation occurs in that part of the island. It was observed that often rain would fall on the mountainous areas and completely bypass the coastal

lowland area in the southwestern part of the island. The flora is a good indicator of the distribution of rainfall on St. Croix. Cactus abounds on the eastern end of the island and the trees appear gnarled and **stunted**. Conversely, on the northwestern part of the island the trees are large and in some valleys, such as the Caledonia valley, there is jungle-like vegetation. From 1852 to about 1945 there were numerous rain-gaging stations in the central part of the island and the records from these stations show that even in the central part of the island the **precipitation** varies greatly; for example, in 1943 the total rainfall half a mile east of Golden Grove was 26.69 inches, and at Bethlehem, about a mile north, it was 13.39 inches greater, or 40.08 inches.

The average annual rainfall from 1852 to 1935 was reported by Cederstrom—

/ Cederstrom, D. J., Geology and ground-water resources of St. Croix, Virgin Islands: U. S. Geol. Survey Water-Supply Paper 1067, p. 10, 1950.

as 46.34 inches. This determination was made from records of rainfall at Christiansted, Frederiksted, and Kings Hill. Rainfall measurements made at the Agricultural Experiment Station at Annas Hope since 1930 show the average annual rainfall at this station to be 44.85 inches. The average annual rainfall at the official station at Alexander Hamilton Field for the period 1947-50 was 47.01 inches. Thus the average annual rainfall in the central part of the island is estimated to be about 46 inches. The annual rainfall reported for the period 1852-1935/^{by Cederstrom} and for 1935-50 by the U. S. Department of Agriculture is shown graphically in figure 1. The lowest

recorded annual rainfall was 29.10 inches in 1922 and the highest was 71.44 in 1933.

The following table shows the average monthly rainfall at Annas Hope from 1930 to 1950:

Average monthly rainfall at Annas Hope, St. Croix, 1930-50

January	3.22	July	3.01
February	1.95	August	3.91
March	1.64	September	6.05
April	2.18	October	6.31
May	4.22	November	5.82
June	3.34	December	3.20
		Annual	<u>44.85</u>

The maximum rainfall is in May, September, October, and November and the driest part of the year is from February to April.

The accumulated departure from normal rainfall is shown in figure 2. For this graph the normal annual rainfall was assumed to be 46.0 inches. The graph shows that the rainfall was below normal from 1861 to 1876, when the accumulated departure was about 56 inches below normal. From 1876 to 1920, although there were a few years of below-normal rainfall, the total precipitation was greatly above normal and as a result the accumulated departure reached 44 inches above normal. The rainfall in the period from 1920 to 1930

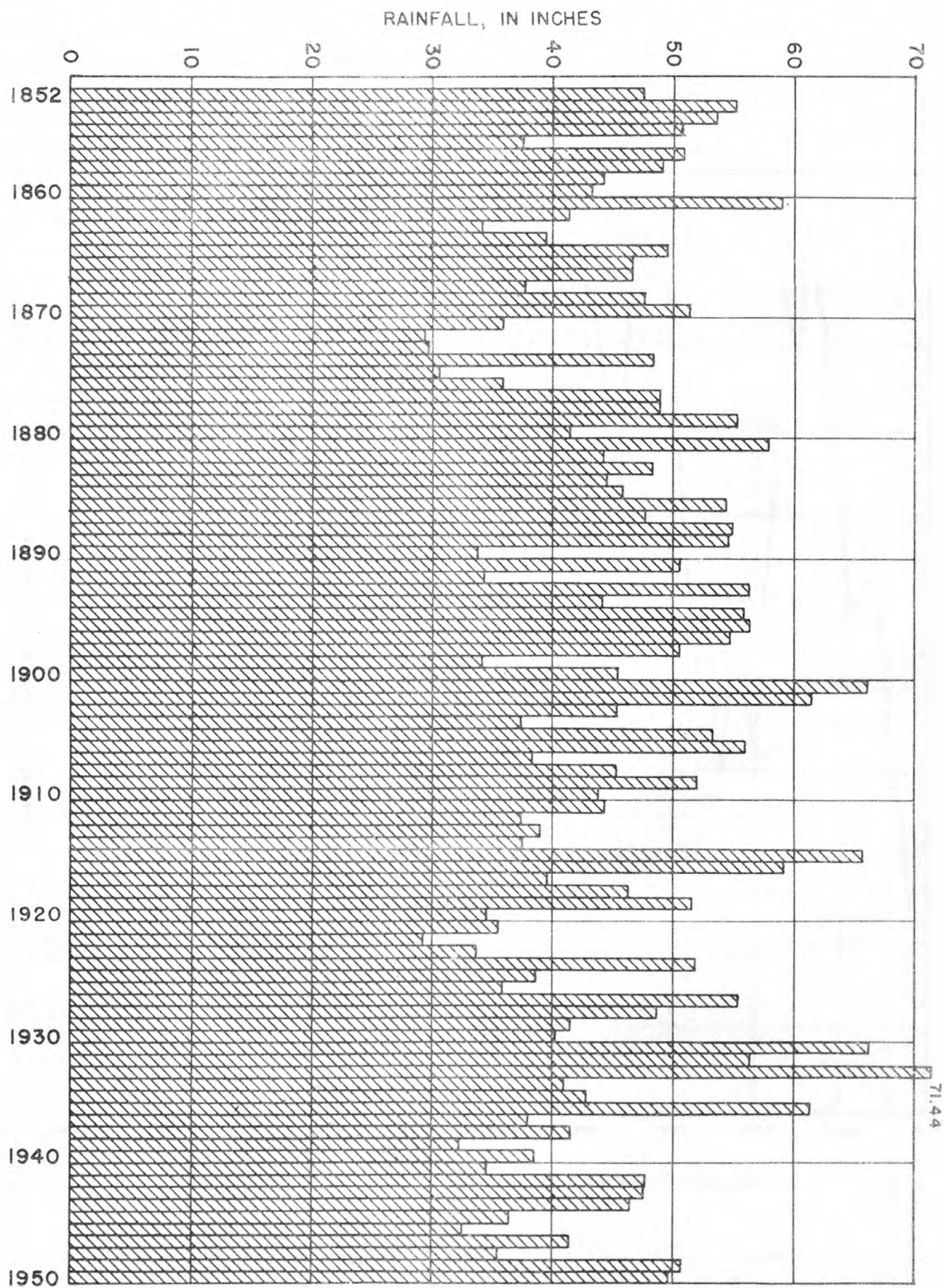


Figure 1.--Rainfall on St. Croix, 1852-1950.

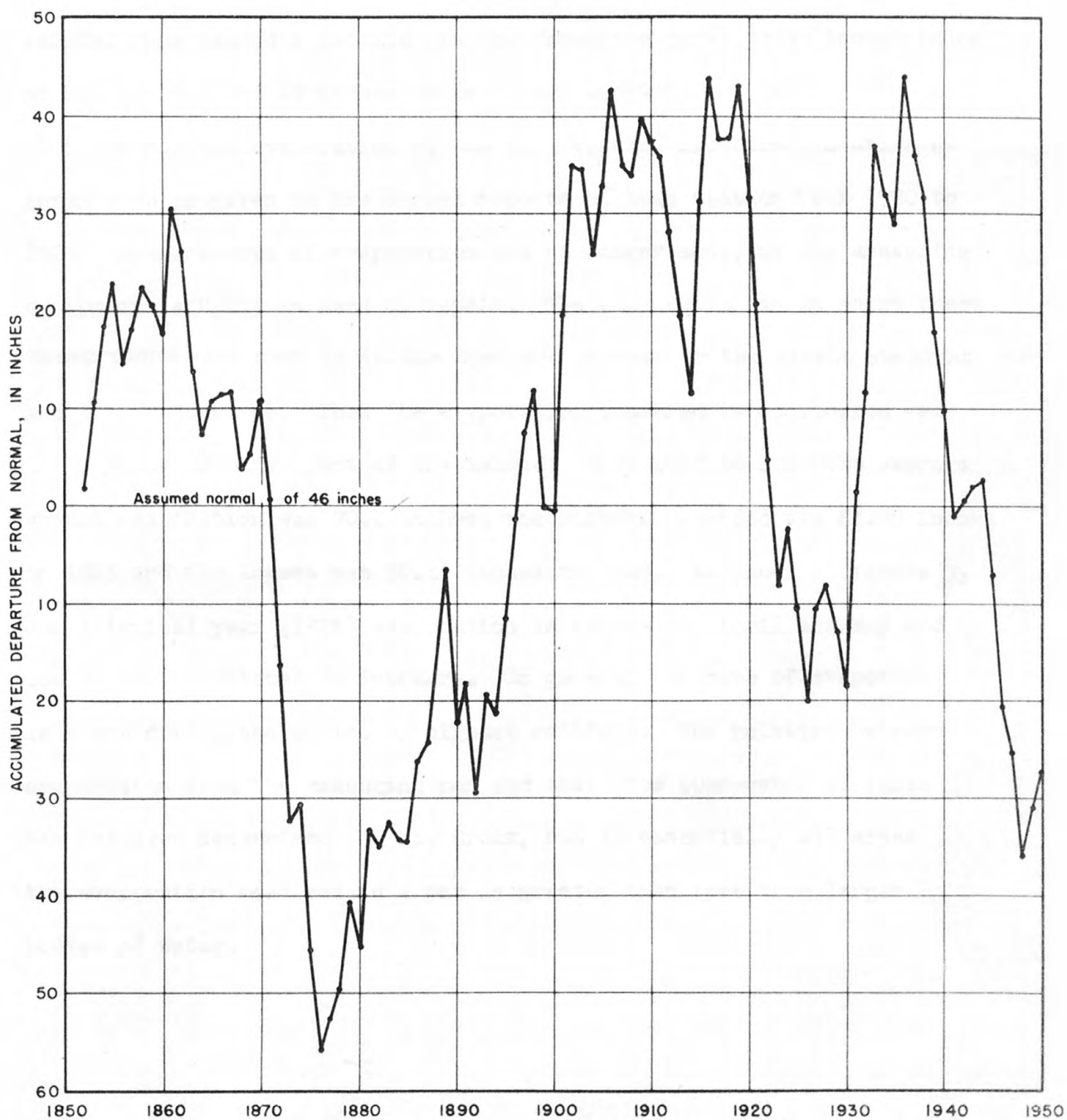


Figure 2.--Accumulated departure from normal rainfall on St. Croix, 1852-1950.

was below normal but by 1936 increased rainfall brought the departure back to about 43 inches above normal. Since 1936 a decline in the annual rainfall has caused a decline in the departure curve to 36 inches below normal in 1948 and 28 inches below normal in 1950.

The monthly evaporation at the Agricultural Experiment Station at Annas Hope is given in the annual reports of that station from 1920 to 1929. Measurements of evaporation are no longer made, as the measuring equipment is badly in need of repair. The evaporating pan in which these measurements were made is in the open and exposed to the direct sunlight and the trade winds. Thus the evaporation measured is considered near the maximum for that part of the island. From 1920 to 1929 the average annual evaporation was 70.2 inches; the highest recorded was 81.80 inches in 1924 and the lowest was 50.11 inches in 1928. As shown in figure 3, for a typical year (1926) evaporation is highest in April and May and lowest during October to February. In general the rate of evaporation is least during the months of highest rainfall. The relation between evaporation from the measuring pan and that from open-water surfaces has not been determined for St. Croix, but in essentially all areas the evaporation measured in a pan is greater than that from larger bodies of water.

Agriculture and Industry

Sugar cane is the principal crop on the island of St. Croix. In the 1920's cane was planted on as much as 18,000 acres; however, owing to the decline in the price of sugar, the acreage became smaller and at present cane is produced on only a few thousand acres. Small trees and brush now grow on much of the land that formerly was used for cane production. The largest single producer of sugar cane on the island is the Virgin Islands Corporation, which has 3,000 to 4,000 acres under cultivation. Much of the pasture land is used for the raising of cattle and sheep. The main industry on the island is the processing of sugar and the manufacture of rum. The tourist trade on St. Croix is much smaller than on the island of St. Thomas; however, efforts are being made to increase this source of revenue.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Cederstrom^{1/} has given an adequate description of the geology of St. Croix;

1/ Op. cit.

consequently, this report will be limited to a brief discussion of the various rock types found on the island and their water-bearing properties. In general two basically different types of rocks form the island: (1) the hard, dense crystalline rocks that form the mountainous area in the northwest part of the island and the submountainous terrane in the eastern part of the island and (2) the younger sedimentary rocks such as the marl and limestone that form the hills in the coastal lowland and the belt of hills immediately east of the Salt River and the alluvium that forms a veneer over most of the marl and limestone in the lowland area, particularly along the streams.

Mount Eagle Volcanics

The Mount Eagle volcanics are the oldest rocks on the island.

Cederstrom^{2/} describes these rocks as largely volcanic in origin. He says,

2/ Op. cit., p. 16.

"Dark fine-grained massive, laminated, or slaty rocks, hard thin- to thick-bedded limestone, and spotted or porphyritic rocks are most common. In some places masses of volcanic breccia made up of angular pieces of dark porphyry or felsite and rounded scoriaceous stones cemented by a fine-grained greenish felsitic material are found." These rocks have been strongly folded and the beds are steeply inclined. Ground water occurs in the weathered and the fractured zones of the volcanic rocks. In general, these zones are most

abundant near the land surface and decrease with depth; consequently, the yield of wells is seldom increased by drilling below a depth of about 100 feet. Records of wells ending in these rocks show yields ranging from 0 to about 30 gallons a minute, the best well yielding $27\frac{1}{2}$ gallons a minute with less than 3 feet of drawdown. The most successful wells drilled in the volcanics are those in the lower part of Little Grange valley that supply potable water to Frederiksted. In the south coastal lowland these rocks are at such a great depth that they have not been encountered by wells, except very near the mountains.

Diorite

Diorite forms the bedrock in the mountainous area between Fountain and Mount Eagle and between Southgate Pond and Great Pond in the eastern part of the island. Unweathered diorite is a hard light-colored coarsely crystalline rock, but in most exposures the rock has been weathered into a brown crumbly soil. These rocks are more easily weathered than the adjacent Mount Eagle volcanics, and thus the valleys of the East Branch and West Branch have been deepened and broadened into their present basin-like shape. As in the Mount Eagle volcanics, ground water occurs in the fractured and weathered zones in the diorite. Cederstrom ^{1/} reports that a

^{1/} Op. cit., p. 50.

well about half a mile north of Jealousy ending in weathered diorite had a yield of $19\frac{1}{2}$ gallons a minute with a drawdown of 15 feet at the end of 6 hours of pumping.

Jealousy Formation

According to Cederstrom^{2/} the outcrop area of the Jealousy formation is

^{2/} Op. cit., map, p. 20.

restricted to a thin band about a mile long northwest of the Jealousy estate and another thin band less than 1,000 feet long at the Fountain estate. The relatively thin calcareous conglomerate exposed in the stream valleys near the Jealousy estate is considered to be the basal conglomerate of the formation. In the coastal lowland the dark clay underlying the Kingshill marl has been assigned to the Jealousy formation. A test hole near Bethlehem showed the gray clay to have a minimum thickness of 1,398 feet, but the maximum thickness is not known because the base of the formation was not reached. The Jealousy formation is composed primarily of impermeable material and therefore is not considered to be a water-bearing formation.

Kingshill Marl

The Kingshill marl is composed of calcareous clay or marl and included beds of limestone. These sediments overlie the Jealousy formation and, where the Jealousy formation is not present near the mountains, they overlie the older Mount Eagle volcanics and diorite. They form a basin-like structure which crosses the island between Salt River and Annas Hope, and they extend westward between the northwest mountainous area and the south coast of the island. The hills in the lowland area and east of the Salt River are formed by the most resistant limestone beds, which have been compressed into folds whose axes trend east-northeast. The thickness of the Kingshill marl is approximately 600 feet east of the Salt River, but the thickness determined

from drilled wells in the vicinity of Bethlehem show the subsurface thickness to be from 77 to 108 feet. Wells ending in the Kingshill marl obtain moderate quantities of water from the beds of limestone. The marl or clay in the formation is very impermeable and wells ending in it are unsuccessful.

Alluvium

The alluvium on St. Croix is composed of sand, gravel, and clay derived from the rocks forming the mountainous and hilly areas of the island. Streams have deposited these sediments in the lower reaches of the small valleys draining the mountains and have spread them across the lowland areas. Alluvium covers a large part of the coastal lowland area as a relatively thin veneer; however, the thickness is much greater in some of the stream channels. For example, at Cotton Valley and Cotton-garden in the eastern part of the island drilled wells showed the thickness to be 69 and 83 feet, respectively. Drilled wells in the valley of the West Branch show the thickness of the alluvium to be at least 83 feet, but a short distance from the center of the valley alluvium is absent and the underlying Kingshill marl is exposed. Thus the greatest thicknesses of alluvium are near the centers of the existing valleys. The largest-yielding wells on the island have been developed in alluvium along the valley of the West Branch near Fair Plain. Cederstrom/ reports that one well (the principal well used

/ Op. cit., p. 61.

by the Virgin Islands Corporation for the Bethlehem factory and the distillery near Christiansted) was pumped at a rate of 80 gallons a minute and at the end of 2½ hours the pumping level was 35.33 feet below the land surface. The static water level before pumping began was 16.83 feet below the surface; thus the well had a yield of slightly more than 4 gallons a minute per foot of drawdown. Along some parts of the valleys the sand and gravel beds contain large amounts of clay and consequently yield only small quantities of water to wells.

DAM SITES

Purpose of Dams

On St. Croix, as on many other small islands in the Caribbean area, there is an annual shortage of water. During the greater part of the year the streams in much of the upland area and in the coastal lowlands are dry and the water table is below the beds of the streams. During and after a period of heavy rainfall there is occasional flooding in the streams. After these periods of concentrated rainfall the flow of the streams gradually decreases and if there is no additional rain the stream beds will again be dry in a short time. It is proposed to construct a series of small earth dams across the streams wherever practical to store the water that now flows to the sea and is wasted. These small reservoirs or ponds are intended to store water for use in irrigating the cane fields, for manufacturing processes, and for domestic and stock supply. Some of the ponds would also be a source of recharge to the ground-water reservoirs along the streams, and a part of the water thus stored could be recovered through wells.

Loss of Water from Ponds and Drainage Areas

The capacities of the existing and proposed ponds are relatively small. Because recharge to the ponds is not continuous but is limited to the few times in the year in which the streams have a flow, it is important to consider the amount of water that will be discharged from the ponds and drainage area by natural processes and what might be done to reduce this natural discharge. Water losses from a pond and its drainage area are restricted essentially to evaporation, transpiration by plants, leakage of water through the dams, and ground-water flow under or around the dams.

Evaporation

As previously stated, the average annual evaporation from 1920 to 1929 was 70.2 inches. This average evaporation was determined by measuring the water loss from an evaporating pan (land pan) that was exposed to both the sun and the wind and represents somewhat more than the maximum amount of water that would be lost annually from an unshaded pond surface that was not protected from the nearly constant trade winds. There is no basis for determining a factor by which to correct the land-pan figures to show probable evaporation from larger free-water surfaces on St. Croix, but a common correction factor is about 0.7 and that figure will be used in this report. Assuming an annual

/ Harding, Sidney T., in Hydrology, Physics of the Earth Ser., vol. 9, edited by Oscar E. Meinzer, p. 75, McGraw-Hill Book Co., Inc., 1942.

evaporation of about 50 (70×0.7) inches, the average daily water loss from a unit pond area of 10,000 square feet would be 854 gallons a day. The rate of evaporation depends largely upon temperature and wind movement. Both these factors are affected by the type and density of the vegetation around a pond of water and in the drainage area supplying the pond. Vegetation, by shading the pond surface and soil, reduces the temperature, thus reducing the evaporation; also, by slowing down wind movement it retards the replacement of moist air with drier air, thus reducing evaporation. For example, in the extreme northwest part of St. Croix the west-trending Caledonia valley is heavily shaded and protected from wind movement. Owing to that shade and lack of wind movement, and in part to the greater rainfall in this part of the island, the valley is very humid and the heavy blanket of vapor would reduce evaporation from open-water surfacesⁱⁿ/the valley. Conversely, a pond in the valley west of the Jealousy estate

is not protected from the sun and the trees have been removed from the east bank, exposing it to the east trade winds. It was reported that, although there was no visible evidence that the dam was leaking, the loss of water from the pond was relatively large. The evaporation from the pond is not at a maximum rate, for there are a few trees along the upper end of the reservoir which give it some shade. However, assuming the annual evaporation to be 50 inches, the loss from the pond from evaporation alone is estimated to be about 7,000 gallons a day or about 5 gallons a minute. This amount may represent the largest part of the reported water loss from the pond.

Evaporation from the soil in the drainage area supplying a pond reduces the amount of water that is potentially available to the pond. As in evaporation from an open body of water, evaporation from soil also is controlled by temperature and wind movement; however, other important factors, such as the type of soil, vegetal cover, and amount of water available, must be considered in determining the water loss from the soil of a drainage area. In forested areas vegetation and litter reduce both the temperature of the soil and the movement of wind, thus reducing direct evaporation. Conversely, the evaporation from a soil containing no vegetation or litter is great.

The rate of evaporation is greatest near the surface where the soil is exposed directly to the wind and the sun. Beneath the surface the rate and depth of evaporation are dependent on the physical properties of the soil and depth to the water table. The depth to which evaporation takes place has been estimated by Lassen and others: "On fine-textured upland soils where the

/ Lassen, Leon, Lull, Howard W., and Frank, Bernard, Some fundamental plant-soil-water relations in watershed management: U. S. Dept. Agr., Forest Service, p. 20, July 1951.

water table does not influence evaporation, water loss is generally limited to

the first foot of soil. In soils possessing more avenues for escape of the vapor particles, evaporation may take water from depths as great as 5 to 6 feet. Such cases, however, require a lengthy dry season for as soon as the surface soil is dried out, the rate of evaporation is greatly reduced."

The most important element controlling the amount of evaporation from soils is the amount of water available. Immediately after a rain the rate of evaporation is high, as there is an abundance of water to be evaporated. After the surficial supply is dissipated evaporation continues at a greatly reduced rate even though the wind and temperature remain high. In areas where the water table is near the surface, discharge from this saturated zone will continue until the water table is lowered below the depth to which water will rise by capillarity near enough to the surface for evaporation to be effective.

In summary, the evaporation loss from soils is controlled primarily by the amount of water available, the vegetal cover, and the physical properties of the soil. Thus the water losses from soil are much less than the losses from an open body of water such as an evaporating pan. There has been no study of soil-evaporation losses in the drainage basins on the island of St. Croix, and consequently it is not possible to estimate accurately the amount of water returned to the atmosphere by evaporation from the island.

Transpiration

The amount of water returned to the atmosphere by the transpiration of plants on the island of St. Croix is possibly greater than the amount of water removed from the island by all other processes. Each plant continues to remove water from the soil or water table to the depth that its roots penetrate until the wilting point of the plant is reached and, if moisture is not soon supplied,

the plant dies. Thus, in a study of the loss of water from ponds and the drainage areas supplying the ponds, consideration must be given to the factors involved in transpiration and, on the island of St. Croix, what can be done to reduce the consumption of water by plants.

One of the chief factors controlling the amount of water used by a plant is the amount of water available to the plant. In general, the greater the amount of water available the denser the growth and the greater the amount transpired. Transpiration differs from evaporation in that the water from the soil zone or water table is removed with equal ease throughout the entire depth to which the plant roots penetrate. Also, if one layer of soil contains more moisture than the adjacent layers, greater quantities of water will be pumped from the wet layers, thus tending to bring the entire root zone to the same moisture content. Lassen and others / have reproduced some moisture-extraction

/ Lassen, Leon, and others, op. cit., pp. 26-27.

curves which show that the rate of transpiration is a function of the moisture content; the greater the content, the more rapid the rate of transpiration. The curves also show that, with a low soil-moisture content, the transpiration rate is low; also, although after a short period of rainfall the soil moisture will be increased in the upper part of the root zone, the rate of transpiration will increase in that part of the zone and tend to bring the entire zone to the same moisture content.

In the unsaturated zone above the water table plant roots obtain water principally from the films adhering to the soil grains with which they are in contact. In general, lateral movement of water in this unsaturated zone is very slight beyond a few inches from the roots. Thus, in general, plants that develop deep and dense root patterns are able to consume more water than those

having shallow and poorly developed roots.

There has been no study of the rate and amount of transpiration in the Virgin Islands, and, as the vegetation is somewhat different from that in the areas where transpiration has been studied, the results of those studies may not be applicable. In tank experiments abundant water is supplied to plants, resulting in a maximum rate of transpiration for the plant tested. In this method of determining transpiration the plant is grown to maturity in a sealed tank, after which the plant material is dried and weighed. The transpiration ratio (pounds of water per pound of dry matter) is then computed from the amount of water required to produce that given quantity of dry matter. Lee/ reports

/ Lee, Charles H., in Hydrology, Physics of the Earth Ser., vol. 9, edited by Oscar E. Meinzer, p. 278, McGraw-Hill Book Co., Inc., 1942.

that results for a single plant variety show consumption in some cases to be more than twice that in others, depending principally on the climate and soil-moisture content. The difference in plant species and climatic conditions on the island of St. Croix makes it impracticable to apply transpiration ratios determined elsewhere on similar plants to the vegetation on the island.

Horton/ has proposed an empirical formula for determining transpiration

/ Horton, R. E., Transpiration of forest trees: Monthly Weather Rev., vol. 51, p. 569, 1923.

from a stand of forest trees:

$$T = \frac{d h N}{10,000} \times \frac{E}{45}$$

in which T = transpiration rate, in inches of depth per acre

d = breast-height diameter of tree, in inches

h = height of tree, in feet

N = number of trees per acre

E = annual evaporation, in inches

This formula does not take into consideration several factors controlling the amount of transpiration, most important of which is the consideration of the amount of water available to the plant.

Thus it is not possible with the available data to make a reliable estimate of transpiration in any part of St. Croix.

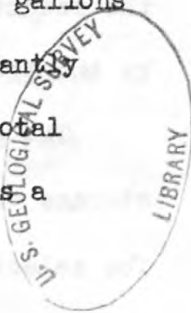
Total Evaporation

Total evaporation is the sum of evaporation and transpiration. On St. Croix transpiration probably removes more water from the soil than evaporation removes from the small inland bodies of water and the soil, for transpiration acts on a greater volume of soil than does direct evaporation. It is not possible with the available data to separate these two elements, and consequently they must be considered together. Total evaporation may be determined for an area by subtracting the total stream flow and ground-water flow from the basin from the water derived from rainfall in the area. As previously stated, the amount of rainfall varies greatly from the east to the west end of St. Croix, but it averages approximately 46 inches annually in the vicinity of Bethlehem near the center of the island. Thus, for the drainage area supplying the East and West Branches, the amount of water available is assumed to be 46 inches annually. The area of the drainage basin is 6,400 acres; thus the amount of water available is 8 billion gallons a year, or an

average of 21.9 million gallons a day. It is understood that many years ago the flow of one of the streams was measured for a year, but since then the records have been lost and at present there is no record of the flow of any stream on the island. It is reported that during the rainy season East and West Branches have a flow that continues from several days to a week or more. From this description of stream flow and the approximate cross-sectional area of the stream channel it is estimated that the average surface runoff is about 1 to 2 billion gallons a year. Ground-water runoff, or underflow, from the drainage area is equally difficult to estimate, owing to lack of data. However, as ground-water flow makes up such a small percentage of the total amount of water involved, estimates of the permeability and differences in head may be greatly in error without affecting appreciably the percentage of total evaporation from the drainage area. The permeability of the marl underlying the alluvium is assumed to be nearly zero; thus all but a very small percentage of the ground-water flow from the valley passes through the relatively narrow channel of alluvium near Fair Plain. The measured width of the valley is about 0.2 mile, and assuming the field permeability of the alluvium to be 200, the average thickness of the alluvium

Gallons per day through 1 square foot at unit hydraulic gradient, at prevailing temperature.

to be 75 feet, and the hydraulic gradient as 50 feet per mile, the ground-water flow from the drainage area (excluding the effect of pumping from the wells in the lower course of the West Branch) would be about 150,000 gallons a day or 0.5 billion gallons a year. This would not change significantly the uncertain figure given previously for surface runoff; thus the total surface and ground-water runoff would be about 1 to 2 billion gallons a



year and the total evaporation would be 6 to 7 billion gallons a year or about 75 to 90 percent of the total water available. As stated, the information upon which the above estimates are made is extremely meager and the estimate of total evaporation may be considerably in error; however, the author believes that, according to reports by inhabitants of the island, the estimates of both surface-water and ground-water runoff are near the maximum; consequently, the computed percentage of the total water lost by total evaporation is believed to be a minimum figure. In years of below-normal precipitation, because evaporation and transpiration have the first claim on rainfall, the amount of water lost by total evaporation may be more than 90 percent of the amount of water available.

Methods of Decreasing Total Evaporation

To help increase the amount of water available to the existing and proposed ponds and to reduce the amount of water lost directly or indirectly from the ponds, the total evaporation from the drainage basins of the island should be reduced as much as possible. To reduce evaporation it might, or might not, prove desirable to (1) plant trees, of types that require a minimum amount of water, along the east banks of the ponds to shade the water and function as windbreaks, and (2) add vegetal litter and a cover of grass or herbaceous plants in the drainage area to reduce the soil temperature and hinder the movement of wind. Before such protective planting is done, however, a study should be made so that it may be estimated whether the reduction of direct evaporation would equal or exceed the use of water by the trees or herbaceous plants.

The greatest opportunity to increase stream flow and ground-water storage on the island is decreasing the amount of water transpired by plants. The selective removal of plants of high water requirement from the drainage

basins of the East and West Branches would decrease transpiration losses and make more water available for beneficial uses. An example of the increased yield from a drainage area caused by cutting forest vegetation is reported by Hoover. On experimental watersheds at the Coweeta Experimental Forest in North Carolina all woody vegetation was cut between January 6 and March 31, 1941. "To prevent disturbance to the soil, trees were left where they fell and no material was removed." The cuttings formed a loose mulch cover over the area, protecting the soil from evaporation and wind movement. During 1942 the new sprouts were cut but in 1943 no cutting was done and the reestablishment of vegetation proceeded rapidly. As a result of the cutting the increased flow for the first 6 months was 8.16 inches. The increased flow for the water years (November to October) 1941-42 and 1942-43 was 16.74 and 10.68 inches, respectively. It is evident that the decrease in flow during the year 1942-43 was caused by the new growth in the drainage area in that year. Although removal of vegetal cover may tend to increase the rate of evaporation, it is obvious from this and other experiments that if the removal is done properly and the soil is protected by litter the amount of water lost through evaporation would be much less than that used by the vegetation.

/Hoover, M. D., Effect of removal of forest vegetation upon water-yields: Am. Geophys. Union Trans., pt. 6, pp. 969-975, 1944.

Complete removal of vegetation, exposing bare soil, would greatly increase evaporation and decrease the permeability of the soil. The impact of rain breaks up the soil and deposits fine material in the existing pore spaces. This tends to compact the soil and form an impermeable layer that

reduces the amount of water entering the soil, and thus it increases erosion. The practice of putting litter between the rows in the cane fields to protect the soil structure and reduce evaporation losses should be continued.

Loss of Water through Dams

All the proposed dams and most of the existing dams are of the earth-fill type. Earth dams are essentially simple structures composed of natural unconsolidated material and consequently are generally the most economical type to construct. Dams of this type are generally used where the amount of water to be impounded is relatively small; however, some earth dams more than 200 feet high have been built and are considered major engineering structures.

The material used in the construction of earth dams is ideally a mixture of sand and gravel with a small amount of clay. Material of too high a clay content is generally unsuitable for earth-dam construction because of the problem of cracking when dry. The sandy material in the alluvium along the valleys of the East and West Branches appears to be suitable for constructing dams along these streams. The most suitable material is that beneath the channels and bordering the streams. Leakage through properly constructed well-compacted earth dams should be negligible, whether or not cut-off walls of puddled clay or concrete are included.

Loss of Water by Ground-Water Flow

The loss of water by the flow of ground water under or around dams is controlled principally by the type of rock underlying and bordering the dam. In the areas underlain by crystalline rocks ground-water flow is restricted essentially to the fractures in the rocks. Thus the loss of water under

or around a dam that has its foundation on crystalline rock would be negligible unless the rock is highly fractured.

The Kingshill marl is composed of limestone and marl. As evidenced by the yield of wells, the limestone may contain solutional openings that transmit water freely. Hence the water loss under a dam constructed on a permeable limestone may be great. The marl in the formation is very impermeable and there would be little or no leakage under a dam seated on this material.

The alluvium that overlies the Kingshill marl is composed of sand, gravel, and clay. In general, it is relatively thin on drainage divides between the streams and thickest in the valleys and along stream channels. In places these stream-laid deposits have been mixed and have a low permeability, but there are some beds of sand and gravel that contain little or no clay and therefore transmit water freely. During most of the year the water table in the alluvial deposits is low and generally below the beds of the streams; consequently there is a relatively large underground storage capacity that could be filled by water leaking from ponds underlain by these deposits. The rise of the water table caused by leakage from such ponds would be confined to the local area underlain by alluvium near the pond and would not extend widely throughout the island.

Leakage may be great beneath earth dams with foundations of undisturbed sand and gravel. Where the thickness of the alluvium is not great, cut-off walls may be constructed to eliminate, where desired, this type of water loss from the proposed ponds. In the areas where the alluvium is thick, as at Fair Plain, it may be necessary to inject a consolidating grouting material such as cement, bentonite, asphalt, liquid plastic, or chemicals (such as sodium silicate and calcium chloride) to eliminate ground-water flow beneath the dams. To determine what method must be used to eliminate loss of water beneath dams it

is necessary to drill test holes to determine the character and thickness of the alluvium at the proposed sites. During the field investigation for this report 12 test holes were completed at 8 proposed dam sites in the valleys of the East and West Branches between the mountains and the Center Line road (the main east-west road passing through Kings Hill). After sites are finally selected along these streams it will be necessary to drill additional test holes at each site to determine the exact thickness and character of the sediments in the valleys at the sites.

Some of the existing earth dams on both the East and West Branches show the effect of leakage through the alluvium. At Lower Love two relatively large dams have been constructed and the reservoir areas above the dams have been deepened and widened to increase their capacity. The bottoms of both reservoirs have been excavated about 3 to 4 feet into the underlying impermeable marl. In August 1951 the water level of the lower pond was slightly below the contact of the marl and alluvium and, according to reports, it seldom declines below that level. There was no indication that water was leaking through the dam. During periods of high pond level there probably is a loss of water into the approximately 10 feet of alluvium that overlies the marl, but when the pond level declines below the marl contact this leakage is eliminated. The water level in the pond immediately upstream from the south pond at Lower Love is in some places above the contact of the marl and alluvium. Immediately downstream from the dam forming this pond the soil is saturated in a small area and there is an abundant growth of water grass and reeds. It appears that this dam leaks, at least at its base, and there is a loss of water into the alluvium when the pond level is high. However, when the pond level declines to the marl contact the leakage from the pond is greatly reduced, but at that level its storage capacity is small.

Several years ago a dam was built on the East Branch about half a mile north of Bethlehem. It is understood that, although a concrete core was incorporated in the center of the dam, beds of sand and gravel exposed by excavation resulted in so much leakage that this pond retains water for only 2 to 3 months after it has been filled. On September 19, 1951, there was a moderately heavy rain in the mountains and in the vicinity of this dam which resulted in filling the pond to within about 2 feet of its spillway. Although during the following 5 days there was a small amount of rainfall daily the level of the pond declined about 2 feet. There was no evidence of leakage through or at the base of the dam itself, showing that the loss of water was beneath the dam or into the alluvium bordering the pond. Another example of leakage into the alluvium is at the dam constructed about half a mile north of Diamond. The bottom and sides of the reservoir area are composed of alluvium, and when visited in September 1951 the pond was completely dry. Even if the proposed dams are constructed with cut-off walls and grouting of the foundations, a large amount of water may enter the alluvium from the proposed ponds along their sides. If this water can be recovered by constructing wells or if it may be used beneficially by crops the water would not be considered to be lost; however, if the water cannot be recovered or put to beneficial use, leakage into the alluvium should be eliminated if possible. If the bottoms of the ponds are not treated the leakage may be relatively great, particularly during the first few years; however, as silt is deposited in the pond area, the pore spaces will gradually be filled with fine material and leakage will decrease. If there is undesirable leakage into the alluvium it would be advisable to treat the bottom and the sides of the ponds, such as by applying a thin layer of clay or bentonite, to form a seal.

Silting of Reservoirs

To maintain the initial capacity of existing and proposed ponds, measures must be provided for the removal of silt, sand, and gravel from the pond beds or methods must be devised for the entrapment of this material before it enters the proposed ponds. Unless there are exceptionally high velocities in the streams the material deposited in the ponds will be progressively finer grained from the mountains to the sea. In the mountainous area the steep gradients of the streams enable the water to transport coarse material that may quickly fill a pond with debris. An example of the effect of siltation is shown by a dam in the mountains near Betsys Jewel. The reservoir area of this 10-foot-high concrete dam is completely filled with sand, gravel, and boulders and on the downstream side of the dam a hole has been eroded and is partly filled with water. The capacity of Creque reservoir, formed by the largest dam on the island, has been greatly reduced by siltation.

On the East and West Branches the proposed ponds nearest the mountains will accumulate the greatest amount of silt and coarse material, as the upper dams will function as sediment traps for the downstream ponds. There appears to have been considerable sedimentation in the pond about half a mile north of Bethlehem. It was noted in September 1951, when the pond was partly filled by a moderately heavy rainfall, that the water was brown and very turbid and remained so for more than a week, by which time the pond was nearly dry. The sediment carried by the water was apparently high in organic content and may not provide an effective seal

on the bottom of the pond. The exact depth of the silt in this pond is not known; however, if it were removed in dry weather the bottom of the pond could be treated to reduce the loss of water by leakage.

Even if effective erosion control is achieved, there will be some erosion of silt from the highlands and deposition of sediment in the ponds downstream. Thus it will be necessary to provide for maintenance of the existing ponds and, after they are constructed, the proposed ponds. In time, if such a maintenance program is not carried out, the ponds will be partly or completely filled with silt and, as at the dam at Betsys Jewel, will be useless. Moreover, if there is no maintenance new stream channels may be formed during flood stages, thus increasing erosion and destroying productive land. The construction of sediment traps immediately above some of the proposed ponds would decrease the amount of sediment entering the ponds. This practice should be particularly effective in the ponds near the mountains. In the ponds downstream the silt may be so fine that sediment traps will be of no use. Removal of silt from the ponds and maintenance of the dams, spillways, and drainage basins will constitute an unending project requiring a certain amount of work each year.

Potential Yield of Drainage Basins

To predict the amount of water discharged through stream flow from a drainage basin would require basic data on the past stream flow and its correlation with precipitation, total evaporation, and ground-water storage. On St. Croix records of precipitation are the only data available and, although these records are adequate for a part of the island, the distribution of precipitation throughout the island is not known. Records

of stream flow are not available and it has been necessary in this report to estimate the annual stream flow from verbal reports on the duration of flow during rainy seasons, and the estimates are correspondingly unreliable. No data have been collected on annual changes in ground-water storage and experiments have not been made on transpiration losses. Thus no prediction of the amount of water available to proposed ponds is warranted.

The accumulated departure from normal rainfall, shown in figure 2, indicates that during a succession of wet years (as from 1880 to 1920) there may be a relatively large supply of water to the ponds. In a series of years of deficient rainfall the stream flow will, of course, decrease. Thus it is planned to construct a large number of dams to save the maximum quantity of water during years of high precipitation for use during succeeding dry years.

Water is vital to the agricultural and industrial prosperity of the Virgin Islands, and it is therefore recommended that a program be started and continued to collect and study data on the water resources of the islands.

Proposed Dam Sites

Mr. Colón of the Virgin Islands Corporation selected the streams to be studied in regard to the selection of dam sites. The streams were selected so that the proposed ponds would be constructed on or would benefit publicly owned property. The streams studied were the East Branch, the West Branch, that passing through Little Grange, and the Salt River. The Little Grange valley and the Salt River valley are the catchment basins for the public-supply well fields of Frederiksted and Christiansted, respectively. One site was studied north of the Virgin Islands Corporation land, at Grove Place. The sites in the following descriptions have been numbered consecutively (see fig. 4).

Little Grange Valley

In this report the valley draining part of the mountainous area on the west end of St. Croix and extending from near Frederiksted through Little Grange and Orangegrope is called the Little Grange valley. During August and part of September there was no surface-water flow in any part of the drainage area. In the latter part of September there was sufficient rainfall to cause a small amount of discharge in the valley above Jolly Hill, but this flow disappeared beneath the surface and below Jolly Hill the stream was dry.

Three possible sites have been selected in this valley between La Grange and Little Grange. Ponds at these three sites would store water that could be used for the public supply at Frederiksted and would be a source of recharge to the well field now supplying potable water to the existing wells. However, as there is no plan at present to enlarge the potable-water distribution system and increase the use of potable water at Frederiksted, it may not be advisable to construct these dams until plans are made to increase the capacity

of the public supply or unless and until there is evidence of an impending shortage of water from the existing wells.

Site 1.--Location. About 0.4 mile northeast of La Grange and about 200 feet south of sharp bend in the channel. (See fig. 4.)

The reservoir area of the site is underlain by alluvium whose thickness is unknown but probably does not exceed a few tens of feet. To determine the extent, thickness, and character of the alluvium below the surface it will be necessary to drill a series of test holes. Bedrock (Mount Eagle volcanics) is exposed in the stream bed about 500 feet downstream from site 1; however, the proposed site appears to be near the center of the old stream channel extending westward to the sea, and the thickness of the alluvium at the site may be relatively great. At site 1 beds of coarse gravel and sand are exposed along the banks of the present stream channel and a pond at this site undoubtedly would cause recharge to the alluvium. As this site is near the existing well field, some of the water seeping from the pond into the alluvium may enter the bedrock and move to the wells.

A dam at this site would be approximately 100 feet long and 20 feet or more high. There is adequate sandy material available at the site for the construction of the dam. The capacity of the dam could be determined only by means of a detailed topographic map; however, above the dam site the valley widens and the stream is braided, thus the capacity and the area covered by water may be fairly large, increasing the potential rate of recharge to the alluvium.

Site 2.--Location: About 0.4 mile downstream from road intersection at Little Grange and about 100 feet upstream from barbed-wire fence.

Crystalline rock is exposed on the side of the valley but the center of the valley at the dam site is underlain by alluvium. The thickness of the

alluvium at the dam site is not known but, as rock crops out in the channel a short distance upstream, it is estimated that the thickness of the alluvium is about 15 feet or less. Unless a well-developed system of fractures is encountered in the bedrock, leakage from the pond would be negligible. If leakage occurred, it might be recoverable from wells constructed near and downstream from the dam. Because of undergrowth it is difficult to estimate the capacity of a dam at this site without the aid of a detailed topographic map; however, it appears that a moderate-sized pond would be formed by a dam about 20 feet high and 200 feet long. Gates in a dam at this site would allow water to be discharged from this pond to maintain the level in the pond at site 1.

Site 3.--Location: About 0.25 mile downstream from road junction at Jolly Hill at upstream end of concrete reservoir.

The proposed dam site is underlain by the Mount Eagle volcanics. In the channel of the stream there are a few boulders and pockets of alluvium. The volcanic rocks are fractured, but sufficient silt would be deposited in the pond bed to seal off most of the leakage. A dam at this site could be built so that the west wing would be anchored to the east corner of the existing concrete tank and the east wing against the high bank across the stream. The dam would be about 20 feet high and about 150 to 200 feet long. It could be constructed so that the spillway emptied into the existing concrete reservoir or tank and the excess water could pass over the existing spillway of the tank. Thus additional storage would be available in the tank. At present the existing concrete tank is fed by a 12-inch concrete pipe extending upstream to a very small and partially filled dam at Jolly Hill. The pipe is in very poor repair and from appearances most of the water entering the pipe at the Jolly Hill dam is lost by leakage. A metal pipe 4 inches in diameter leads downstream from the concrete tank. This existing pipe could be used to release

water from site 3 to sites 1 and 2.

The pond capacity at site 3 is estimated to be 2 to 4 million gallons; however, a topographic survey is needed to determine both its capacity and the maximum height to which the dam could be built without flooding the valley road.

Grove Place

Site 4.--Location: About 0.25 mile north of Grove Place, at the constriction in valley west of a blue cottage on the main road and immediately downstream from a cane field on a terrace on the northeast side of the valley.

The sides of the valley are composed of soil-covered crystalline rocks, but near the center of the valley and in the channel the surface is underlain by clayey alluvium. It is estimated that the thickness of the alluvium near the channel is only a few feet. From a preliminary investigation of the site it does not appear that there would be appreciable leakage through the clayey soil or crystalline rocks under or around the proposed dam.

It is estimated that at this site a dam about 25 feet high would be approximately 250 feet long. The reservoir formed by the dam would flood part of the small cane field immediately above the dam but no other productive land would be affected, as only about a dozen large trees and some small trees and brush occupy the pond area. The capacity of the pond could be increased by increasing the dam height, and a topographic survey would be required to determine the optimum height of the dam required.

There are no suitable sites on the property of the Virgin Islands Corporation downstream from site 4. Thus it may be feasible to build this dam, which has an untapped drainage area of about 400 acres, to store water for use in the fields at the west side of the Corporation's property.

West Branch

The valley of the West Branch extends from near Fair Plain, where it meets the East Branch, northward through Castle Burke, River and Fountain. During the dry time of the year there is no flow in the lower reaches of the stream and only a small amount of water appears in places along the channel in the upper reaches of the stream. There are nine dams along the main channel and its tributaries from Lower Love to Fountain. In addition to these nine existing dams, possible sites for seven additional dams have been selected on the property of the Virgin Islands Corporation. Construction on these dams could begin immediately so that as much water as possible may be stored in the coming year.

Site 5.--Location: Immediately below confluence of East and West Branches near Fair Plain.

At the proposed site the alluvium-filled valley is about 800 feet wide. Test wells have been drilled near the center of the valley, showing the alluvium to be at least 73 feet thick and to contain water-bearing beds of sand and gravel. The Kingshill marl is exposed on both sides of the valley and forms the bottom of the ancient valley that existed before the alluvium was deposited. Before the proposed dam is constructed a series of test holes should be drilled across the valley to determine accurately the thickness and character of the alluvial sediments. After the permeable beds are located it may be necessary to consolidate the material by injecting grout of some type to eliminate ground-water flow beneath and around the dam. Beds of sand and gravel are exposed along the banks of the stream and, as the water table is at or below the bed of the channel, there will undoubtedly be movement of water from the pond into the adjacent alluvial material. As the water table rises the leakage from the pond will be gradually reduced until the water table is near the level of the pond. The water lost from the pond and

stored in the alluvium of the valley could be put to beneficial use. Several wells have been drilled along the proposed pond area and are producing water for use at the airport and the Central factory. As the amount of water stored in the alluvium is increased by percolation from the pond, larger quantities of water may be recovered from existing wells and new wells may be drilled to utilize more fully this ground-water storage reservoir.

A topographic map is being made of the area along the valleys of the East and West Branches from Fair Plain north to near Bethlehem. After this map is completed the exact sites and capacities of the proposed ponds can best be determined. The proposed dam at site 5 is estimated to be about 200 feet long and about 20 to 25 feet high. The capacity of the existing channel area will not be known until the topographic map is completed; however, the existing capacity may be enlarged by excavation along the channel and across meanders. The capacity of the pond at this site will be greater than that of any other pond in the coastal area, as it will extend some distance up both the East and the West Branches. There appears to be adequate sandy material in the area to be excavated that would be suitable for use in construction of the earth dam.

Additional sites were not selected between site 5 and site 6, between Golden Grove and Adventure, as the topographic map of the area being made was not yet completed. In general, the channel of the stream between these two sites is U-shaped, about 10 to 15 feet deep, and has a maximum width of about 50 to 100 feet. Location of additional dam sites along this section of the stream would depend upon the distance upstream that the lower dam ponds the water. Thus, after the map is completed, it may be possible to select several dam sites between sites 5 and 6. The potential leakage from these sites and the benefits therefrom would be similar to those described for site 5.

Site 6.--Location: Between Golden Grove and Adventure, immediately below the confluence of the streams from Castle Burke and Hard Labor.

Alluvial sand, gravel, and clay are exposed along the banks of the stream in the proposed pond area of this site. The thickness and character of the alluvium were determined in two test holes drilled on the banks of the stream. The first hole was drilled on the east bank at the confluence of the main channel and an abandoned meander and about 10 feet above the bed of the channel. The material penetrated was as follows:

<u>Thickness (feet)</u>	<u>Depth (feet)</u>	<u>Description</u>
Alluvium		
12	12	Sandy clay, brown
2	14	Gravel, small amount of clay, brown; water appeared in hole
2	16	Sand, coarse, mixed with small amount of brown clay; hole caved at 16 feet
5	21	Sand, coarse, mixed with small amount of brown clay and gravel (necessary to insert casing to stop caving)
2	23	Sandy clay, brown, gravel, free
14	37	Sandy clay, light-brown, small amount of gravel
Kingshill marl		
1	38	Marl

Note: Water level 10 feet below land surface

Material penetrated in the test hole drilled on the west bank of the stream and about 10 feet above the channel was as follows:

<u>Thickness (feet)</u>	<u>Depth (feet)</u>	<u>Description</u>
Alluvium		
7	7	Sandy clay, brown
3	10	Sandy clay, brown, mixed with gravel and limestone
3	13	Sandy clay, brown, mixed with gravel

2	15	Sandy clay, brown
5.5	20.5	Clay, brown, gravel; water entered the hole
Kingshill marl		
2.5	23	Limestone, hard
2	25	Marl

Note: Water level 11.5 feet below land surface

These two test holes indicate that the thickness of the alluvium is at least 37 feet near the center of the old channel, and that water-bearing sand, gravel, and possibly limestone are present that would cause water to flow under the proposed dam. Although further testing will be required, it appears that there is enough permeable material to yield water to drilled or dug wells in the alluvium at this site. Hence it may be possible to avoid treating the foundation material, and to use wells around and below the pond to recover the water that leaks into the alluvium. Additional test holes will be needed to outline in detail the alluvium-filled channel and to determine whether it will be advisable to construct wells or to endeavor to seal the material beneath the proposed dam and pond.

A dam at this site would be about 100 to 200 feet long and a maximum of 15 feet high. The capacity of the reservoir may be increased by excavation, and the material excavated from the reservoir area probably would be suitable for the construction of the dam.

Site 7.--Location: On the tributary of the West Branch extending northward between Plessen and Lower Love and about 200 yards upstream from site 6.

Alluvial sand and gravel are exposed along the stream bed and the banks of the channel are covered with clay. The thickness of the alluvium in this tributary is not known but, as the drainage area of this stream is smaller than that of the main channel and the flow of the stream is less, it is possible that the depth to marl is less than at site 6. If this site is selected for construction it would be advisable to test drill to determine the thickness

and character of the alluvium.

The exact location of the dam may best be selected when the topographic map is completed. The stream channel is about 50 feet wide and has an average depth of about 8 feet. The capacity of the reservoir will depend to a great extent on the amount of excavation along the channel.

Site 8.--Location: About 200 yards upstream from site 7, below small ditch draining cane field from the east.

The geology and dimensions of the stream at this site are similar to those described for site 7. A topographic survey will best determine if it will be advisable to build a dam at this site. The capacity of the dam will be relatively small and will depend mainly on the amount of excavation. It is possible that during high pool stages a part of the bordering cane field will be flooded.

Site 9.--Location: Between Lower Love and Center Line road; about 100 to 200 feet north of Center Line road.

The Kingshill marl is exposed on the east bank of the stream about 200 feet from the stream channel, and alluvial sand and clay are exposed in the channel and on the relatively flat land to the west. To determine the thickness and character of the alluvium near the stream two test holes were drilled at this site. A test hole was drilled about 5 feet from the west bank of the stream at an altitude of about 10 feet above the bed of the channel. The following material was penetrated:

	<u>Thickness</u> (feet)	<u>Depth</u> (feet)	<u>Description</u>
Alluvium	4	4	Clay and sand, brown
	7	11	Gravel and sand, slight amount of clay
	2	13	Sandy clay, brownish-gray
	5	18	Sandy clay

Kingshill marl

1

19

Clay, white, tough

Note: Water level 11.7 feet below land surface, September 27, 1951

A second test hole was drilled about 95 feet west of the above-described test, at the edge of what appeared to be an old meander of the stream. This test hole was about 2 feet lower in altitude than the first test hole. The following material was penetrated:

<u>Thickness (feet)</u>	<u>Depth (feet)</u>	<u>Description</u>
Alluvium		
4	4	Soil and clay
2	6	Clay, mixed with gravel
2	8	Clay, slight amount of gravel
6	14	Sandy clay, gray
1	15	Gravel and some sandy clay; water seen entering hole
1	16	Sandy clay
Kingshill marl		
1	17	Marl

Note: Water level 10.6 feet below land surface, September 27, 1951

West of the second test hole at site 9 the alluvium becomes thinner. It is believed by the writer that within 100 feet west of the second test hole the alluvium-marl contact is within a few feet of the surface; however, if a dam is constructed at this site it would be advisable to drill additional tests to outline in more detail the extent of the alluvial fill. Much of the material encountered in the test holes contained large amounts of clay and would not transmit water freely. In drilling additional test holes, larger lenses of sand and gravel than that logged between 14 and 15 feet in the second test hole may be encountered that would result in leakage beneath the proposed dam. To eliminate such leakage it may be necessary to construct a cut-off wall extending

to the marl, or to grout a section across the fill. Much of the alluvium exposed in the stream bed is clayey and thus it is doubtful if a large amount of water would be lost from the pond to the alluvium adjacent to the pond. The capacity of the pond can best be estimated after the topographic map is completed; however, to increase the reservoir capacity the existing channel area can be excavated to a considerable extent without using bordering productive land. At the site the stream channel is about 10 to 15 feet deep and about 50 to 100 feet wide at the approximate pond level.

Site 10.--Location: Immediately below the confluence of the streams from Lower Love and Castle Burke; near the old mill tower on west bank of stream.

Silt and clay form most of the outcrops near the proposed dam site and in the reservoir area. Two test holes were drilled at the site, one near the center of the stream and the other on the east bank of the stream near the edge of the cane field. The following material was penetrated in the test near the center of the stream:

	<u>Thickness (feet)</u>	<u>Depth (feet)</u>	<u>Description</u>
Alluvium	5	5	Sandy clay, brown
Kingshill marl	1	6	Clay, white, tough

Note: No water in hole

Following is the log of the test hole drilled on the east bank:

	<u>Thickness (feet)</u>	<u>Depth (feet)</u>	<u>Description</u>
Alluvium	6	6	Sandy clay, brown
	4	10	Sandy clay, small amount of gravel
	3.5	13.5	Sandy clay, brown
Kingshill marl	1	14.5	Clay, white, tough

Note: No water in hole

These test holes show that the marl-alluvium contact is at or near the bed of the stream channel, and thus the base of the pond and dam would rest on the impermeable marl and there should be little or no leakage beneath the dam. The alluvium contains much clayey material, and unless gravel beds are exposed by excavation in the reservoir area upstream from the dam there will probably not be much lateral leakage from the pond into the alluvium. As the pond base will be excavated into the marl the water-retaining capacity of the proposed pond probably would be similar to the dams at Castle Burke and Lower Love.

At the site the channel is 10 to 15 feet deep and the banks are slightly more constricted than they are downstream. The pond area contains many large trees that will need to be removed to decrease the rate of transpiration and enable the pond to be deepened. Thus the capacity of the pond depends to a large extent on the amount of excavation made in the reservoir area extending up both streams.

Four dams have been built on the stream extending northward from site 10 through Lower Love. The drainage area above the southernmost dam is only 350 acres and, as it is reported that there has never been an overflow from this dam, it appears that the existing four dams are more than adequate for the small drainage area supplying the ponds. If it is desirable to increase the capacity of the dams in this drainage area it would be advisable to remove the accumulated silt and deepen the reservoirs of the two small northernmost ponds, which function partly as sediment traps for the lower dams.

Site 11.--Location: At bend of stream above Castle Burke and about 100 yards downstream from old railroad crossing the stream.

Alluvial sandy clay is exposed along the stream bed and no beds of permeable sand or gravel were found in the proposed pond area. The exact thickness of the alluvium is not known but the marl is estimated to be within

a few feet of the channel bed. Thus the base of the proposed pond and dam would be in the Kingshill marl and unless a permeable limestone is encountered there probably would be little or no leakage under the dam. As the alluvial material contains a large amount of clay, it is doubtful if there would be much lateral leakage from the pond into the alluvium.

A topographic map having a contour interval of 1 foot has been completed for the area that includes this proposed pond. The capacity of the present channel, as estimated from this map, is about 1.5 million gallons. Excavation of the pond area would increase the capacity by possibly 1 million gallons.

On the West Branch north of site 11 there are no suitable dam sites on property owned by the Virgin Islands Corporation.

East Branch

The valley of the East Branch extends northward from its confluence with the West Branch near Fair Plain to Bethlehem, thence northwestward to near Solitude. During August and part of September 1951 the stream had no flow; however, in the latter part of September there was a small flow in the upper reaches for a few days following a period of relatively heavy rainfall in the mountains and near Bethlehem. There are two dams along the main channel of the stream north of Bethlehem. The dam about 1 mile north of Bethlehem is reported to retain water for only a few months after the rainy season. A small dam near Hermitage is reported to leak badly and the reservoir is dry during most of the year. In addition to the existing dams, sites for nine additional dams have been selected on the property of the Virgin Islands Corporation and two in the stretch within about half a mile upstream from the Corporation's property line.

During the operation of the sugar factory at Bethlehem, sugar-mill waste is discharged into the stream a short distance above the Center Line road. The amount of effluent discharged is not known, but if it is great enough to cause

objectionable pollution of the downstream ponds it may be advisable not to construct the dams, or to use other means for the disposal of the effluent. Additional sites on the East Branch between sites 5 and 12 can best be selected when the topographic map of the area is completed. It is thought that the pond area of site 5 will not extend as far upstream as site 12.

It is proposed that the alluvium in the valley from near Bethlehem to Fair Plain be prospected thoroughly by test drilling to determine the presence of water-bearing sand and gravel beds from which water stored in the alluvium by leakage from the proposed ponds may be recovered through wells. If it is determined to be possible to obtain water from drilled or large-diameter dug wells, the total amount of water that could be recovered from the valley for beneficial use would be much greater than could be obtained from the proposed series of ponds alone.

Site 12.--Location: About 0.6 mile upstream from the confluence of East and West Branches at sharp bend in channel.

The Kingshill marl is exposed about 100 to 200 feet east of the bed of the stream. The channel and banks of the stream are covered with silt and it will be necessary to drill test holes to determine the thickness and character of the alluvial deposits at this site. From the data obtained from test holes upstream from this site it is evident that the alluvium is sufficiently thick so that excavation of the pond area will not expose the underlying marl. At this site it is probable that sand and gravel are present in the alluvium and will transmit water beneath and around the proposed dam. This leakage from the pond will raise the water table and thus increase the ground-water storage in the valley.

The proposed dam probably would be about 100 feet long and about 10 to 15 feet above the existing bed of the channel. Although the material exposed at the surface contains a large amount of clay, adequate sandy material may be

present and, if so, would be made available during the excavation of the reservoir area, for the construction of the dam. The water that may leak beneath and around the dam could be put to beneficial use, and thus it may be desirable not to treat the permeable material below the dam and across the valley to stop such leakage.

Site 13.--Location: About 0.25 mile upstream from site 12 at sharp bend in stream that is partly dammed by gravel.

The geology at this site is practically the same as that at site 12; thus it is probable that there may be some lateral leakage into the alluvium and beneath the dam. At site 13 the channel is U-shaped, about 7 feet deep, and 30 feet wide. This U-shaped channel extends upstream for about 150 feet, then narrows to about 20 feet; however, the capacity of the pond could be enlarged by excavation. Although much of the channel is covered by dried sugar-mill effluent, it is believed that adequate sandy material is available at the site for the construction of the dam.

Site 14.--Location: About 300 yards upstream from site 13 and immediately below abandoned meander on east side of stream.

Fragments of limestone are abundant in the cane field on the east side of the stream, indicating that the east wing of the dam would be seated on the Kingshill marl. The center and the west wing of the dam would be underlain by alluvium. The exact thickness of the alluvium is not known; however, data from test holes upstream indicate that even after excavation the marl will not be exposed in the center and at the west side of the pond. The channel of the stream is about 25 feet wide and 10 feet deep. The capacity of the pond may be increased and dam material may be supplied by excavating in the old meander on the east side of the stream.

Another small dam may be constructed between site 14 and the Center Line road; however, it may pool water under the bridge at Center Line road and, owing to the discharge of plant effluent into the stream above the bridge, the present

unpleasant odor might be accentuated.

Site 15.--Location: Between Center Line road and Bethlehem and about 500 feet north of Center Line road, immediately upstream from the plant-effluent discharge point..

The site is underlain by alluvial sand, gravel, and clay. One test hole was drilled about 15 feet from the west bank of the stream to determine the character and thickness of the alluvium. The test hole was about 8 feet above the altitude of the stream bed. The following material was penetrated in the test hole:

<u>Thickness</u> (feet)	<u>Depth</u> (feet)	<u>Description</u>
Alluvium		
2	2	Sandy clay, brown
6	8	Gravel, sand, and clay, mixed
3	11	Sandy clay, some gravel
3	14	Sandy clay, brown
Kingshill marl		
4	18	Marl, white; a little sand imbedded in marl

Note: Water level 9.6 feet below land surface,
September 27, 1951

As a test well upstream at site 16 encountered marl at a depth of 33 feet, it is evident that the test hole at site 15 was not drilled in the deepest part of the old valley and that the maximum thickness of the alluvium at this site is more than 14 feet and probably at least 30 feet.

Much of the material penetrated in this hole contained a large amount of clay and was very impermeable. For example, when the hole was completed the drilling water was bailed out and more than 5 days was required for the water to seep into the hole up to the level of the water table. It is possible that other test holes would encounter permeable material, but if this one test is representative there would be very little leakage beneath a dam at this site. However, permeable beds might be exposed in the pond area that would transmit

water laterally from the pond into the alluvium.

The channel of the stream at the site is about 40 feet wide and has an average depth of 8 to 10 feet. The material penetrated in the test hole contained considerable quantities of clay but enough sandy material may be present in the pond area for constructing the dam.

Site 16.--Location: About 700 feet upstream from site 15 at sharp northward bend in stream.

The dam site and pond area are underlain by at least 33 feet of alluvium, as shown by the following log of a test hole drilled near the center of the old meander on the west bank of the stream and about 9 feet above the bed of the stream:

	<u>Thickness (feet)</u>	<u>Depth (feet)</u>	<u>Description</u>
Alluvium			
	4	4	Soil and sandy clay, brown
	6	10	Sand and gravel, coarse, few lumps of sandy clay, brown
	.5	10.5	Sandy clay
	.5	11	Sand and gravel
	1	12	Sandy clay, brown, some gravel
	4	16	Sand and gravel, coarse, some sandy clay
	2.5	18.5	Sandy clay, hard drilling
	1.5	20	Sand, gravel, and clay
	1.5	21.5	Sand and gravel
	.5	22	Sandy clay
	3	25	Sandy clay, brown, some gravel
	5.5	30.5	Clay, brown, and sand, coarse, some gravel
	2.5	33	Sandy clay, brown, impermeable, some gravel
Kingshill marl			
	1	34	Clay, light gray, tough

Note: Water level 12.7 feet below land surface, September 25, 1951

The material penetrated in the test hole was relatively impermeable and, with the exception of a few thin beds of sand and gravel in the upper 16 feet of the section, it would not be considered water bearing. The amount of gravel encountered, however, indicates that there may be some permeable material beneath the proposed site that would permit some leakage beneath the dam.

The channel of the stream at site 16 is about 8 to 10 feet deep and if the dam is constructed at the meander its maximum length would be about 150 feet. It is possible to enlarge greatly the capacity of the pond by excavation of unproductive land above the dam site. The log of the test hole indicates that there will be adequate sandy material at the site for the construction of the dam.

Site 17.--Location: Between site 16 and road between Bethlehem and Fredensborg.

After the topographic map of the area is completed it may be found possible to construct a dam between site 16 and the road between Bethlehem and Fredensborg without causing the road to be flooded during high pond stages. If it is found to be feasible to construct the dam the geologic and hydrologic conditions would be similar to those described for site 16.

Site 18.--Location: About 200 feet north of the road between Bethlehem and Fredensborg and downstream from the confluence of the main stream and its northward-trending tributaries.

The Kingshill marl is exposed on the east bank of the stream; thus the east end of the proposed dam will rest on the impermeable clay of that formation. The remainder of the valley and the plain extending west from the site are underlain by alluvium. To determine the character and approximate thickness of the alluvium two test holes were drilled in the valley. The first hole was drilled about 75 feet west of the base of the east bank and about 4 feet above the lowest part of the channel. The following material was penetrated:

<u>Thickness (feet)</u>	<u>Depth (feet)</u>	<u>Description</u>
Alluvium		
2.5	2.5	Clayey soil, brown
1.5	4	Gravel
4.5	8.5	Clay, brown
1.5	10	Gravel, coarse
2	12	Clay, brown, and gravel mixed with clay
2	14	Gravel, some sandy clay
2	16	Sand and gravel; gravel fine
2	18	Clay, yellowish-brown
Kingshill marl		
2	20	Clay, light-gray

Note: Water level 11.1 feet below land surface, September 13, 1951

The second test hole was drilled about 110 feet west of the first test hole and just east of a large licorice tree. Following is the log of this test hole:

<u>Thickness (feet)</u>	<u>Depth (feet)</u>	<u>Description</u>
Alluvium		
4	4	Clayey soil, brown
3	7	Gravel
.5	7.5	Clay and gravel
5.5	13	Sand and gravel
2	15	Gravel, slight amount of clay
Kingshill marl		
2	17	Clay, light-gray, some sand and gravel imbedded in clay
2	19	Clay, light-gray

Note: Water level 11.7 feet below land surface, September 14, 1951

The test holes show the presence of permeable sand and gravel beds underlying the area of the proposed dam; thus, unless a cut-off wall is extended to the Kingshill marl, a considerable amount of water will be lost by seepage beneath the dam. There will be essentially no leakage around the east wing of the dam but, as the extent and thickness of the alluvium west of the dam are not known, water that enters the alluvium adjacent to the pond may flow downstream and around the dam. The sand and gravel penetrated in the test holes were sufficiently permeable to yield water to wells; however, at present the saturated thickness of the material was only about 5 feet. If the water table in the alluvium is raised by leakage from the pond, the saturated thickness of the water-bearing material will be increased and thus the potential yield of wells drilled or dug into it will be larger.

The valley at site 18 is relatively broad and shallow. The height of the dam would be about 10 to 15 feet above the present stream channel; its length can best be determined by a topographic survey but will probably be at least 200 feet. There is adequate space for excavation to increase the reservoir capacity, and the material obtained from excavation probably will be suitable for dam construction.

Site 19.--Location: About 400 yards upstream from site 18 and about 150 feet north of large palm tree on the west banks of the stream.

Beds of sand and gravel are exposed in the banks of the stream and a test hole drilled on the west bank of the stream and about 8 feet above the bed of the channel penetrated the following material:

<u>Thickness</u> <u>(feet)</u>	<u>Depth</u> <u>(feet)</u>	<u>Description</u>
Alluvium		
6	6	Clay, brown
2.5	8.5	Gravel and sand
1.5	10	Sand, gravel, and clay
6.5	16.5	Sand and gravel, coarse

Kingshill marl

1.5

18

Clay, light-gray

Note: Water level 10.8 feet below land surface, September 15, 1951

The test hole showed that the impermeable marl is at least 8 feet below the bed of the stream and that permeable sand and gravel are present within this interval. Thus it is very likely that, unless a cut-off wall is constructed, there will be leakage through the sand and gravel beneath the dam. The thickness of the alluvium east and west of the site is not known but it is probably less than it is near the stream channel. There probably will be some loss of water into the alluvium adjacent to the pond, and it is probable that the water-retaining capacity of the dam would be similar to that of the existing dam about half a mile north of Bethlehem.

The channel of the stream is about 8 to 10 feet deep and 50 to 100 feet wide. The material obtained from excavating the reservoir area will probably be suitable for earth-dam construction.

Site 20.--Location: About 350 yards upstream from site 19 and about midway along the section of the stream trending east-west.

A test well along the south bank of the stream and immediately below the upstream confluence of the stream and an abandoned meander and about 9 feet above the stream bed, showed the site to be underlain by the following material:

<u>Thickness</u> <u>(feet)</u>	<u>Depth</u> <u>(feet)</u>	<u>Description</u>
Alluvium		
8	8	Clay, brown
2	10	Sandy clay, brown
3	13	Gravel
1	14	Clay, sandy, brown
Kingshill marl		
1	15	Clay, white, and gravel
1	16	Clay, white

Note: Water level 12.2 feet below land surface, September 18, 1951

Thus the impermeable clay of the Kingshill marl is at least 5 feet below the center of the present channel and some of the material is permeable enough to transmit water under the dam if leakage is not prevented by grouting or by a cut-off wall extending to the white clay. It is probable that there may be leakage from the pond into the adjacent alluvium, similar to that at the existing dam about 400 yards upstream.

The stream channel is about 10 feet deep and 25 feet wide. There is adequate material suitable for dam construction that may be obtained during the excavation of the reservoir area.

Site 21.--Location: About 450 yards upstream from the existing dam half a mile north of Bethlehem and about 250 yards upstream from the road between Jealousy and Fredensfeld. The dam site is near an old mill tower.

Proposed sites 21 and 22 are on private property north of the Virgin Islands Corporation property boundary line. These ponds could be used to store water for use on Corporation property, or for release of water through gates to maintain pool levels at the dams downstream.

The Kingshill marl is exposed in the channel of the stream that would form the reservoir area at site 21. Alluvial sand and gravel are exposed in the banks and bed of the stream at the dam site. The exact thickness of the alluvium is not known but it is estimated to extend not more than a few feet below the bed of the present channel. The exposed gravel is coarse and appears to be very permeable; thus there may be some leakage of water around the proposed dam. Leakage from this dam would benefit only its immediate vicinity, so that if it is desired to prevent such leakage test holes should be drilled across the valley to determine the water-bearing properties and thickness of the alluvium and the economic feasibility of constructing a cut-off wall or grouting to reduce leakage.

The stream channel at this site has a maximum depth of about 20 feet and width of about 100 feet. There is adequate sandy material for dam construction that could be excavated from the proposed reservoir area. If site 22, about 400 yards upstream, is not constructed the reservoir area of site 21 will intercept most of the sand and gravel washed down from the upper reaches of the stream. Hence it would be advisable to provide for periodic removal of sediment from the reservoir area.

Site 22.--Location: About 400 yards upstream from site 21 and east of a housing development.

The base of the proposed dam would be underlain by the basal hard limy conglomerate of the Jealousy formation. This conglomerate is well indurated and would form a relatively impermeable foundation for the dam. Alluvium is present in the upper part of the stream banks and it is possible that there would be a small amount of leakage around the dam when the pond level was high. This leakage could be reduced by removing any permeable sand and gravel and replacing it with compacted earth material. The base of the reservoir area is underlain by diorite that has been weathered into a clayey granular soil. The stream channel at the proposed site has a ~~maximum~~ depth of about 20 feet and width of about 200 feet. The west bank of the channel is nearly vertical; the east bank has a more gradual rise and is interrupted by a small terrace about 10 feet above the bed of the channel. A dam at this site would function as a sediment trap for the proposed dams downstream. Hence it would be advisable to dig a trap above the dam from which the collected sediment could be removed periodically, or to provide for periodic removal of the sediment from the reservoir area of the pond.

Salt River Valley

Salt River extends from its mouth at Sugar Bay on the north side of the island southwestward to Fredensfeld, thence northwestward through Little Fountain and Betsys Jewel. Although the stream drains an area of about 3,000 acres, it has a flow for only a short time during the rainy season. The well field supplying water for the public supply of Christiansted extends up the valley from near Morningstar to near Glynn. Two proposed dam sites have been selected in the well-field area, whose primary purpose would be to increase the recharge to the water-bearing beds that supply water to the public-supply wells. As there is no plan at present to increase the amount of potable water delivered to Christiansted, it may be advisable not to construct these dams until such plans are made or there is evidence of an impending shortage of water from the existing well field. Two other dam sites have been selected near Fredensfeld and Little Fountain. Some of the water from ~~these~~ dams could be used for irrigation; however, as this drainage area is the source of water for the public supply of Christiansted, it would be necessary to consider the effect of diverting water from these upstream dams out of the drainage area, thus eliminating a part of the recharge to the well field. Adequate studies would show whether the ponds would result in an increase over the natural recharge even if part of their water were diverted, or whether there would be a net reduction in the amount of water available to the wells.

A topographic survey would be necessary to determine whether additional dam sites would be feasible.

Site 23.--Location: Between Little Fountain and Lebanon and about 250 yards upstream from road crossing stream.

The valley is underlain by the crystalline rocks of the Mount Eagle volcanics and the alluvium in the center of the channel consists of sand and boulders that have a maximum thickness of a few feet. The crystalline rocks are exposed in some

places along the scoured-out channel. Alluvium in a secondary channel paralleling the main stream may be as much as 5 to 10 feet thick. Relatively unweathered crystalline rock would form the foundation of a dam at this site. From an examination of the surface exposures these rocks appeared to be relatively impermeable; however, excavation might reveal fractures that would need to be sealed if it is desired to prevent seepage under the dam. It is doubtful, however that leakage from a dam at this site would be great. Further, there is a slight possibility that any seepage might move downstream underground to points where it could enter the water-bearing limestone directly or by way of the overlying alluvium.

The capacity of a dam at this site will depend on the length and height of the dam, which may best be determined by means of a topographic survey of the proposed site. As at site 22, siltation of the reservoir at site 23 will be relatively great, as it will be the dam farthest upstream in its drainage area. Provisions for protection from and removal of silt should be similar to those suggested for site 22.

Site 24.--Location: On property of Virgin Islands Corporation near Fredensfeld, on stream between Glynn and Fredensfeld.

The valley of the stream south of the east-west road at Fredensfeld is underlain by clayey soil and alluvium. The exact thickness of the alluvium is not known but is estimated to be not more than 10 to 20 feet. If a dam is constructed at this site it would be advisable to drill test holes at the selected site to determine the character of the alluvium. The alluvium is underlain by the Kingshill marl, which might or might not include beds of limestone that would be recharged by leakage from the pond.

A topographic survey will be needed to determine the best location for a dam. An altimeter survey showed the gradient of the stream to be about 5 feet per 100 feet between the downstream and upstream bridges crossing the Fredensfeld road; thus it may be possible to construct two small-capacity dams in this section of the valley. The valley is about 150 feet wide and the average depth of the pond would be about 6 feet; thus the capacity of each pond would be about 2 million gallons. The drainage area above the proposed site is only 150 to 200 acres, and consequently it may not be advisable to construct both dams at the same time. If, after the first dam is completed, there proves to be a surplus of water it may then be feasible to construct the second dam.

Site 25.--Location: About 100 to 200 feet upstream from public-supply well 11 and about 150 yards downstream from the confluence of the main stream and the tributary extending southwest to near Fredensfeld.

At the site the valley is underlain by approximately 20 feet of alluvium. Clayey soil is exposed along the sides of the channel; however, the logs of the public-supply wells show that, at least locally, beds of sand and gravel underlie the surface. The primary purpose of the proposed pond would be to create a source of recharge for the water-bearing sand, gravel, and limestone in the valley; hence it is not necessary to construct a watertight dam and pond area. Thus the dam would permit the water to enter the ground instead of flowing over the surface into the sea.

The channel of the stream at the site is about 8 feet deep and 50 feet wide. Above the site the stream has several channels that would increase the storage area of the pond. The water level in a dug well in the bed of the

stream near well 11 showed the water table to be 10 feet below the bed of the stream. Downstream from well 11 the water table was at or near the bed of the stream; thus it appears that the sediments are being dewatered near the wells and that recharge from the proposed pond would make more water available to the public-supply well field.

Site 26.--Location: Between public-supply well 7 and the intersection of the Sugar Bay - Morningstar roads and about 850 yards downstream from site 25.

Alluvial clay is exposed in the channel area; however, the area is similar to that at site 25 and some beds of sand and gravel probably underlie the exposed clay. The purpose of this dam is the same as that for site 25; thus a watertight dam and pond area need not be constructed. Studies should be made to determine whether recharge to the alluvium is effective in replenishing the underlying limestone, or whether wells in the alluvium downstream from public-supply well 7 would be necessary to recover the water.

At the site, the channel is about 8 feet deep and 50 feet wide. The water table in the pond area is about half a foot above the bottom of the channel, so that a small pond was formed, but near well 7 the channel is dry and the water table is below the surface.

CONCLUSIONS AND RECOMMENDATIONS

The greatest handicap in evaluating the water resources of St. Croix is the lack of basic data regarding the hydrologic cycle. Although adequate precipitation records are available for the coastal lowland area near Bethlehem, additional records are needed throughout the island to determine the distribution of rainfall in the various drainage basins. No records are available of the flow of any stream on the island, the fluctuations of the water table, or the amount of water lost through total evaporation. Hence it would seem prudent to start and continue a program for the purpose of collecting and analyzing basic data on the water resources of the island. This program should include: (1) installation of additional rain gages to determine the precipitation throughout the larger drainage basins on the island; (2) selection of sites and construction of stream-gaging stations, at least on Salt River, East Branch, West Branch, and the stream near Little Grange; (3) study of the water losses by evaporation and transpiration and methods of reducing such losses; (4) selection or drilling of observation wells to determine the effect of recharge from precipitation or from ponds and of losses of ground water by evapotranspiration; and (5) a detailed study of the geology and its relation to the occurrence of ground water so that the ground-water reservoirs may be fully utilized. To accomplish these purposes will require competent hydrologists to collect, analyze, and interpret the data, and a competent hydrologic engineer to make the necessary decisions as to location, construction, maintenance, and operation of ponds and wells to make the fullest use of the small available water supply. Half-measures will not do the job and will only result in waste of time and money.

With the meager data available it is not possible to make a sound analysis of the water resources of the island, and thus the optimum number of dams needed in any given drainage basin to retain the unknown amount of stream flow could

not be determined. In the Little Grange valley three possible dam sites have been selected. Site 1 is that probably most suitable for recharging the aquifer supplying the Frederiksted public-supply well field, and therefore priority should be given to the construction of this dam. If there is a surplus of water, dams could then be built at sites 2 and 3. It may not be desirable to construct any of the dams until more water is needed for the Frederiksted public supply.

The drainage area above the proposed dam at site 4 contains no dams and there may be adequate water to supply the reservoir. The water from this reservoir may be fed by gravity to the cane fields in the western part of the Virgin Islands Corporation's property. Storage of water in this reservoir may decrease the amount of water formerly available to the existing dam at Diamond. Stream-flow measurements are needed to determine the amount of this effect.

The dam at site 5 near Fair Plain will have the largest capacity of any proposed reservoir on the coastal lowland. Owing to its capacity and to its potentialities as a source of recharge to the alluvial ground-water reservoir, it is suggested that this dam be constructed before any other dam on the West Branch or East Branch. After the topographic map is completed it may be desirable to construct additional dams between sites 5 and 6 on the West Branch and sites 5 and 12 on the East Branch. Of the proposed sites on the West Branch and East Branch, it would be advisable to construct the largest-capacity dams first, and if there is a surplus of water the smaller-capacity dams may then be built. It is possible that in years of below-normal rainfall few or none of the proposed reservoirs would be filled to capacity.

The proposed dam at site 23 may be constructed so that it forms a relatively large reservoir. It would not be advisable, however, to divert the entire flow of the stream at this reservoir, for this drainage area probably

is the source of a large part of the water pumped from the Christiansted public-supply well field. The proposed ponds at sites 25 and 26 should function as sources of recharge to that well field or to additional wells downstream from well 7.

In general, leakage under and around dams and loss of water through pond bases will be greatest in areas underlain by alluvium and will be negligible in areas underlain by the clay of the Kingshill marl and the crystalline rocks of the Mount Eagle volcanics. However, where it is desired to prevent leakage it will be necessary to do a thorough job, for leakage that would be negligible in a region of effectively wetter climate might mean the difference between success and failure of a reservoir on St. Croix. The rocks underlying each site and the possibility of leakage have been described previously for each site.

The primary purpose of the dam-construction program would be to retain on the land a part of the water that now flows to the sea and is wasted. The proposed dams will create additional surface storage space and, through leakage from the ponds, the water table will be raised in the vicinity of some of the dams. The water may be pumped directly from the ponds to the point of use; however, it will be necessary to drill or dig wells to recover the water stored in the ground. As the greatest seepage of water from the ponds to the water table will take place in the areas underlain by alluvium, it is proposed that the alluvium along the East Branch and West Branch from near Bethlehem to Fair Plain be prospected thoroughly by test drilling, perhaps supplemented by geophysical surveys, to determine the presence of sand and gravel beds that will yield water to wells. With the use of wells the amount of water that may be derived from these valleys will be greatly increased over the amount that would be available from surface storage alone.

Unless the proposed and existing ponds and dams are maintained, the value of the ponds will decrease, in some cases very rapidly. It will be necessary, therefore, to provide for the periodic removal of sediment from the pond areas and sediment traps and for the maintenance of the dams and spillways. If such a program is not continued, the silted reservoirs might cause the streams to form new channels during times of flood, thus ruining productive land.

It is emphasized that the proposed program of building small dams may not represent the best or most economical way to develop the limited water resources of the areas concerned. Only much more detailed hydrologic studies than have been made so far would show (1) whether larger and more expensive dams in the headwater areas might form more permanent and, in the end, more economical means of development and (2) the extent to which ground-water development might supplant, at lower cost, a part of the surface-water development now proposed or that might be proposed in the future.

Thus, the present report is not to be construed as a recommendation by the Geological Survey that the proposed dams be constructed. It represents simply the Survey's opinion of the proposed sites, and on the assumption that the dams are to be built and at the request of the responsible agency.

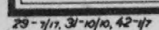


Figure 4.--Map of part of St. Croix showing existing and proposed ponds.



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