PRICING POLICIES, COST ALLOCATION, AND DEMAND IN THE PUBLIC WATER INDUSTRY, U. S. VIRGIN ISLANDS

Part I and Part II

by

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Abstract

In Part I of this report the geological factors that influence the occurance of ground water in the Virgin Islands are presented as well as an examination made of the climatology of the islands. Various extremes in rainfall patterns occuring in recent years are highlighted and factors which militate against the facile use of annual average rainfall estimates for planning purposes are presented. Lastly, the history of the water supply system in the Virgin Islands is summarized.

In Part II a summary of the type of data available on Water Resources in the Virgin Islands is made. One section of this part briefly lists the types of information classified in eight topical forms while the other section is an extended bibliography of the literature available.

PART I

AN INTRODUCTION TO THE TOPOGRAPHY AND CLIMATOLOGY OF THE UNITED STATES VIRGIN ISLANDS INCLUDING A SUMMARY OF THE EVOLUTION OF THE PUBLIC WATER INDUSTRY

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Introduction

The United States Virgin Islands form part of the antilles islands arch, which separates the Caribbean Sea from the Atlantic Ocean. As a group, the islands are located approximately 1,400 miles southeast of New York City, nearly 1,000 miles east southeast of Miami, and almost 50 miles east of Puerto Rico. They are comprised of over fifty islands and cays. The three largest and most important islands are St. Croix, St. Thomas, and St. John whose respective land areas are approximatley 80, 32, and 20 square miles. The smaller islands range in area from slightly less than one square mile to a few hundred square feet.

The terrain of the Virgin Islands is generally rugged, with many steep and sharp peaks. Just as the islands differ in size, so they vary in topographical characteristics. Both St. John and St. Thomas have many slopes exceeding 35 degrees and containing numerous stream courses of steep gradients. On St. Thomas most of the flat land (comprising approximately 5 percent of land area) is confined to areas around Charlotte Amalie, the capital city, and to several narrow beach areas.[1] The land surface is almost entirely sloping and extends seaward from a central ridge, 800 to 1,200 feet high, running

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[1]This topographical description of St. Thomas basically follows D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, (U.S. Geological Survey, Open-File Report, 1973).

the length of the island. The only variation in the general topography is in the upper valley of Turpentine Run in eastern St. Thomas. This valley has relatively gentle topography consisting of rolling hills in a basin surrounded by steep slopes and sharp ridges.

St. John is similar to St. Thomas but has even less flat land.[2] The island of St. John has two populated areas, Cruz Bay on the west end and Coral Bay near the east end, connected by a scenic hard-surface road. Available flat land on St. John is mainly confined to the Coral Bay area.

The shape of the island of St. Croix on the other hand is long and fairly narrow with mountains and hills which form a spine along its entire length.[3] This spine, combined with many valleys, divides the island into many small drainage basins, with few of them containing over six square miles. The northwest part of the island is characterized by a rugged mountainous area with deep valleys, bounded on the south and west by gently rolling lowlands. The central portion of the island is comprised of broad valleys and rounded hills. The eatern part of the island features mountainous terrain with gentler slopes than the mountains of the western reaches. The flatter areas of the island are located

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[2]Oliver J. Cosner and Dean B. Bogart, Water in St. John, U.S. Virgin Islands, (U.S. Geological Survey, Open-File Report, 1972).

[3]P. E. Ward and D. G. Jordan, Water Resources of the Virgin Islands: A Preliminary Appraisal, (U.S. Geological Survey, Open-File Report, 1963).

predominantly along the south coast. Streams on the island are not perennial, but flow only during periods of very intensive rainfall.

As is common with other tropical areas, in the Virgin Islands there are more or less definite wet and dry seasons. The former extends from August through November, and the dry season from January through April or May. February and March are the driest months, whereas, September is the wettest.[4] The rainy season is coincident with the hurricane season. Rainfall in the Virgin Islands averages about 44 inches per year. Although the climate is unusually clear and sunny, the air temperature is moderate because of the persistent trade winds. The prevailing direction of the wind is east-northeast, but east and southeast are common; west winds are rare.[5] Air temperature ranges from a mean low of 72.0°F in February to a mean high of 87.8°F in August. The highest daily temperature of record was 95°F and the low 63°F. Relative humidity is high due to the proximity of the sea, averaging 81 percent in the early morning hours, and lowest, averaging 66 percent, in the early afternoon.

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[4]P. E. Ward and D. G. Jordan, Water Resources of the Virgin Islands: A Preliminary Appraisal, (U. S. Geological Survey, Open-File Report, 1963), p. 1.

[5]This and the following climatic data are taken directly from D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, (U. S. Geological Survey, Open-File Report, 1973), pp 2. ff.

Although the islands lie in the path of hurricanes, major rainstorms are rare. Maximum rates of rainfall occur during the passing of hurricanes and lesser tropical storms, which generally occur during the months of August, September and October.[6] The greatest rainfall of record was 18.0 inches, September 13-14, 1928, during a hurricane.[7] Tropical storms move through the area and occasionally deluge the islands with heavy rain. Nevertheless, direct hits by such storms have been infrequent in recent years. Hurricanes passing within 50 to 100 miles of the islands often cause rainfalls totalling more than 10 inches in a day or two from practically continuous downpours.[8] The last great rain in recent years was 10.6 inches, May 8, 1960, the result of a stationary tropical depression.[9]

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[6] Tippets-Abbett-McCarthy-Stratton, Inc., Potable Water Supply for St. Thomas, Virgin Islands, (San Juan, P.R.: November, 1958), p. 13.

[7] D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, (U. S. Geological Survey, Open-File Report, 1973), p. 2.

[8] Tippets-Abbett-McCarthy-Stratton, Inc., Potable Water Supply for St. Croix, Virgin Islands, (San Juan, P. R.: 1959), p. 19.

[9] D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, (U. S. Geological Survey, Open-File Report, 1973), p. 2.

Special Environmental Features

As previously indicated, average Virgin Islands rainfall is commonly believed to be 45 inches per year.[10] However, in the context of intercountry comparisons, this mean estimate is considered to be over-biased becaused of several quite unique factors deriving from the islands' peculiar topography, climate, and ecology. These features deserve some elaboration on two counts: because of the extreme reliance historically placed on rainfall as the major source of domestic water supply; and because of the critical interface of these factors with the task and scope of the present study.

In the first place, annual rainfall varies widely, ranging between 25 to 55 inches per year. Only about half the time does annual precipitation fall between the tolerable limits of 40-50 inches. Almost 10 percent of the time annual rainfall is less than 35 inches.[11] This latter instance usually means a major short-fall during the wet season with an ensuing period of severe drought. Thus, because of this seemingly endemic variance, any average rainfall figure tends to distort the effective level of precipitation.

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[10] P. E. Ward and D. G. Jordan, Water Resources of the Virgin Islands: A Preliminary Appraisal, (U. S. Geological Survey, Open-File Report, 1963).

[11] D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, (U. S. Geological Survey, Open-File Report, 1973), p. 8.

Second, annual rainfall is distributed unequally across the three major islands. To illustrate, the face of St. Croix almost invariably receives less than 40 inches of rain in an average year rather than the 45 inch, all-island average most frequently quoted.[12]

In addition, precipitation falls very unevenly within each of these major islands. This results from a complex of variables involving a rather young and fragile island ecosystem composed of specialized subsystems created by the variegated topography and the constant east-northeast trade winds. Each of these different environments are slightly distinct from the other subsystems in terms of temperature, cloud activity, rainfall, etc.[13] For an example obvious to casual observation, generally the eastern portions of islands in the Virgin chain are more arid than the greener western sections which benefit both from the cloud build-up over the western and central sections and the east-to-west wind channels.

A fourth set of factors which militates against the facile use of annual average rainfall estimates is based on

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[12] Martyn Bowden et. al., Climate, Water Balance, and Climatic Change in the North-West Virgin Islands, (St. Thomas: Caribbean Research Institute, 1970), p. 5.

[13] For some discussion of this intra-island differential precipitation behavior deriving from complex and fragile island ecosystems, see John McEachern and Ed Towle, "Resource Management Programs for Oceanic Islands" Transactions of the Thirty Seventh North American Wildlife and Natural Resources Conference, (Washington, D.C.: Wildlife Management Institute, March 1972).

the very quality and seasonality of the precipitation itself, again in combination with the structure of the topography and the climate. On the one hand, most of the rain falls during short showers that last a few minutes. With the pervasive breezes, the sun almost always shining through the clear relatively pollution-free atmosphere, and a mean temperature of 80.1°F, the evaporation rate is quite high.[14] Moreover, further evaporation results from the tropical confluence of constant wind, warm temperature, and a proclivity of the essentially clay surface to become granular and to expose the moisture retained in deeper soil to air circulation.

This erosion of the moisture base is further accelerated by the heavy incidence of evapotranspiration (through plant life) attributed mainly to the prevalence of dense brush growth common to the islands and trees bordering streams.[15] In summary, the predominant contour of Virgin Islands rainfall is its short duration and scattered distribution; therefore, given the peculiarities of the island environment, the brunt of this portion of the annual aggregate precipitation is quickly returned to the atmosphere. The dynamics of this rapid recycling has led one

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[14] Krisen Buros, "Water and Wastewater Planning and Problems in the Virgin Islands," Address before the Conference: Augmenting the Virgin Islands Water Supply, (St. Thomas: Caribbean Research Institute, Water Resources Research Center, May, 1975).

[15] D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, (U. S. Geological Survey, Open-File Report, 1973), pp. 8-10.

researcher to question the validity of applying the traditional measures of rainfall performance (average annual rainfall) to the special circumstances surrounding the local island ambience.

> Any practical interpretation of the average rainfalls reported in the Virgin Islands ... should take into account the fact that a large portion of the rain falls in light showers and brief sprinkles ... Many of these light rains are measured in rain gauges and they augment the total rainfall out of proportion to their significance...[16]

On the other hand, the large downpours exceeding one inch, accompanied by overcast skies and usually associated with tropical disturbances, are very infrequent, numbering on the average six to seven times per year.[17] However, because of the concentration of precipitation, the steep gradients of the mountainous setting, and relatively high water tables characteristic of volcanic islands, there is excessive runoff and frequent flooding in the low-lying areas near the coastal zone. This type of water loss is further evidence of the unreliability of mean rainfall estimates.

Recent Economic Pressures

This previously mentioned low-retention capacity has been further reduced by massive economic dislocations during

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[16]See Robert Stones, "Meteorology of the Virgin Islands," in Bowden et. al., Climate, Water Balance, p. 40.

[17]D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, (U. S. Geological Survey, Open-File Report, 1973), p. 2.

the tourist and export-manufacturing developments taking place since the early sixties.[18] Natural sheltered areas have been severely encroached upon by housing projects, commercial installations, new highway systems, parking lots and airport facilities to name a few. In effect, former greenbelts have been replaced by hard, non-porous surfaces that tend to step-up the runoff and seriously modify water quality in the process.

In addition, both the rapid pace and the special contours of recent development thrusts have aggravated the already precarious water balance. For example, intensive pressures of urban over-crowding have emerged from at least three major sources: the large resident work force required to service the labor-intensive sectors of tourism and government; the concentration of commercial and governmental activity within the urban cores; and the relatively large inflow of off-island visitors.[19] The predominant response to these increasing densities, during a period of perceptibly rising per capita incomes, has been a disjunctive urban-to-rural migration, a pattern of suburbanization analogous to the

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[18]For a detailed analysis of the remarkable Economic changes in the Virgin Islands since 1960, see Jerome L. McElroy, The Virgin Islands Economy: Past Performance, Future Projections, Planning Alternatives, (St. Thomas: V.I. Planning Office, 1974).

[19]On any given day the number of tourists in St. Thomas (pop. 43,000) exceeds 3,000 adding to a density already above 1,300 persons per square mile. This figure rivals Barbados (1,500+) which has one of the highest densities in the world.

urban sprawl of major U.S. metropolitan areas.[20] This proliferation of suburban home-building generally constructed along hillsides and steep terrains to exploit the seaview has accelerated the runoff rate.

Moreover, these growth-induced manipulations of a tightly integrated island environmental system have caused adverse impacts on other aspects of the fresh water delivery system. These include alterations in natural drainage sheds, ponds, water tables, and saline intrusion in cases of installations intersecting with the coastal zone.[21] Acting in concert, all of the above forces -- light, erratic, and maldistributed precipitation, rapid transpiration, excessive runoff, and unprecedented economic growth -- have twisted the Virgin Islands supply-demand water balance. Perhaps especially the last of these, i.e. over-rapid economic expansion, may have so affected rainfall and retention capacity as to partially explain what seems to be a long-term drying trend in the Virgin Islands as a whole which has appeared in recent decades.[22] This conclusion seems quite

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[20]During the decade between 1960-70, all V.I. central cities declined in absolute population. The urban/rural balance shifted from approximately 55%/45% in 1960 to 25%/75% in 1970. Source: Bureau of Census. Number of Inhabitants: Virgin Islands, 1970 Census of Population, PC (1), A55 V.I., p. 5.

[21]For some local documentation, see McEachern and Towle, Ecological Guidelines for the Development of Islands, Mimeo, (St. Thomas: Island Resources Foundation, 1973).

[22]See Bowden, et. al., Climate, Water Balance, p. 113.

plausible according to systems analysis theory which portrays island ecosystems as a delicate balance of interdependent components that is extremely sensitive to external disturbances and internal adjustments and thus easily thrown into disequilibrium.[23]

Additionally, these same forces have given rise to the search for and creation of rather expensive alternative fresh water sources. These include: salt water production, dam construction, expanded catchments and storage reservoirs, in-house commercial production and recycling plants, importation from Puerto Rico, waste-water reclamation and the like. These initiatives, however, have spawned their own special difficulties. For example, the mis-match of modern desalinization technology with an archaic distribution infrastructure, results in periodic breakdowns and constant leakages. Nevertheless, it is clear that water scarcity will worsen in the face of the heavy commercial and residential consumption projected for the future.[24]

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[23]For a general application of the Equilibrium Ecosystem model to the V.I., see Jerome L. McElroy, "Tourist Economy and Island Environment: An Overview of Structural Disequilibrium," Caribbean Educational Bulletin, Vol. 2 No. 1, (January 1975), pp. 40-58. For more specific applications to local water concerns, see Frank T. Carlson, "The Challenges of Water Resources Management," and Daniel D. Evans, "The Coordination of Water Research, Planning, and Management for Virgin Islands," addresses before the conference: The Virgin and Water Resources, (St. Thomas: Caribbean Research Institute, WRRC, April 1976).

[24]Between 1975 and 2000, water consumption is expected to triple; see Louis Penn, Norman Cassells, and Roy Adams, Population, Economic Activity, and Water Use Projections for the U. S. Virgin Islands, Mimeo, (St. Thomas: V. I. Planning Office, March 1975), pp. 10-13.

To assist in appraising the magnitude of this short-fall and to help rationally plan the development of cost-effective and environmentally appropriate supplies to meet these requirements is the point of departure for the present investigation.

Summary History of the Water Supply System in the U.S. Virgin Islands

Traditionally the principal need of the Virgin Islands, all through its varied history, has been for a dependable and safe potable water supply. Historically, rain water provided the only major source of fresh water, and the irregularity of rainfall made for an unrealiable supply. The effects of this chronic shortage had several dimensions. Though evidence is sparse, there is some indication that the pre-Columbian inhabitants of the islands clustered their campsites in the low lands adjacent to rivers, streams, and bays.[25] Such locations facilitated agriculture, fishing, and transportation and provided indispensable natural water supplies. Undoubtedly the small size and scattered distribution of these early Indian communities partly resulted from the limited availability of fresh water.[26] Even during the

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[25]Cited in Isaac Dookhan, A History of the Virgin Islands of the United States, (Essex, England: Bowker Publishing Company, 1974) Chapter 2, pp. 15-30.

[26]Oliver J. Cosner and Dean B. Bogart, Water in St. John, U.S. Virgin Islands, (U.S. Geological Survey, Open-File Report, 1972), pp. 3-5.

Danish adminstration of the islands, persistent droughts had a major part to play, among other causes, in the gradual demise of sugar monoculture that dominated the St. Croix economy.[27] In a real sense water scarcity perennially constrained the commercial stability of the colonial communities and limited their capacity to produce an ever growing level of livelihoods.

On the island of St. Thomas, Charlotte Amalie was, until recent years, the only seaport and sizeable community. All of the business, trade, and governmental activities on St. Thomas were concentrated within the city including the rum distilleries, the only major industrial establishments, were located along the waterfront strip bordering the sea. Providing a more adequate and safe water supply for Charlotte Amalie was exceedingly difficult during the early post-colonization era for the obvious reasons discussed earlier: extended periods of sub-normal rainfall, geological conditions unfavorable for developing subsurface supplies and conducive to high chlorine content in ground waters, and so on.

From the time of the first settlement on St. Thomas, the major source of water has been rainfall caught on the roofs and stored in barrels or cisterns. Because of the regular cycles of severe drought, however, there was a constant necessity for establishing a larger and more satisfactory

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[27] E. Heilbuth, Denmark and St. Croix in their Mutual Relations.

supply. As early as 1862, a group of private citizens endeavored to promote a public water system to replace or supplement the private supply, which for the poorer classes was almost non-existent. The community organizer who had called the meeting, Mr. M. B. Simmons, pointed out that the reason" ... that water has become an article of import is due to a deficiency in the accommodation for collecting and preserving rain water."[28] A draft proposal for the building of public water reservoirs, nonetheless, was not acted upon at that time.

Virtually no significant public initiatives were taken until after the transfer of the island dependencies to the United States in 1917 when the former colonies were placed under the administration of the U. S. Navy. By the early 1920's, there were about 200 private and 17 public wells in use in the urban area surrounding the capital city.[29] Subsequently in 1924, U. S. Navy Commander R. M. Warfield made a study of the water supply of St. Thomas. In assessing the various sources and relative supplies, he noted the following:

> "It is practicable to obtain a satisfactory supply of potable water by constructing

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[28] Arthur F. Johnson, Water Supply for St. Thomas, Virgin Islands, (U. S. Bureau of Reclamation, Mimeo Report), Exhibit C.

[29] D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, p. 11. After the establishment of the public catchment system in 1926, most of these wells fell into disuse because of sewage and salt-water contamination.

> catchment areas of concrete or corrugated galvanized iron to catch the rainfall and store the water in cisterns for use as required. This method can be employed in any of the Virgin Islands and is the only method recommended for St. Thomas, and Christiansted, St. Croix. The slope of the ground in the immediate vicinity of both of the cities is well adapted to the construction and so located that the water can be distributed by gravity to various points in the cities ..., it is estimated that 80% of the total rainfall on the horizontal projection of the catchment area can be collected and stored in this method."[30]

Following his analysis, Warfield made plans and estimates for five units to be built to furnish water to the then three divisions of the city. Taken together, these catchments provided 356,550 square feet of surface catchment area with a total tank capacity of 3,191,000 gallons. The cost of the entire project was estimated at $211,450.[31] Construction on three and one-half units was completed in 1924. This portion covered 194,500 square feet of concrete slab with a storage capacity in reinforced concrete tanks of 1,657,223 gallons at a cost of $212,690. Table I (page 17) details the status of Warfield's five-unit catchment and storage program as of 1926 in terms of proposed-versus-constructed capacity. Subsequent to 1926 and forward to the present, eighteen additional

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[30] Arthur F. Johnson, Water Supply for St. Thomas, Virgin Islands, Exhibit G. See also R. M. Warfield, Report on Water Supply, Virgin Islands, (U. S. Navy, 1924).

[31] Arthur F. Johnson, Water Supply for St. Thomas, Virgin Islands, p. 21. The rest of these data are from the same source.

public rain catchments have been constructed along hillsides. Of these, fourteen are connected to the public urban distribution system.[32] Presumably those remaining serve institutional users and settlement concentrations outside the city limits.[33]

During the colonial period of the 18th and 19th centuries, St. John was almost entirely under sugar cultivation. Danish settlers developed limited water supplies independently for their respective estates from a variety of small-scale sources.[34] These included the following: digging numerous shallow large-diameter wells; damming stream channels; diverting the outflow of streams; drawing from a few small surface reservoirs along streams and of course constructing cisterns supplied by roof catchments. Aside from the catchment systems, however, most of these private sources proved unsatisfactory. Streams and adjacent ponds were never substantial suppliers because of periodic droughts, excessive runoff during the wet season, and the replacement of the native vegetation with agricultural staples and deep-rooted trees that accelerate evapotranspiration. In addition, the wells

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[32] D. G. Jordan and O. J. Cosner, A Survey of Water Resources of St. Thomas, Virgin Islands, p. 11.

[33] Interpreted from Roger E. Kasperson, Decentralized Water Reuse Systems in a Water Scarce Environment: The Tourist Industry in St. Thomas, Virgin Islands, Water Pollution Report No. 13, (St. Thomas: Caribbean Research Institute, 1971), p. 4.

[34] This section is taken porsim from Cosner and Bogart, Water in St. John, p. 5, 37-38.

TABLE I

Proposed and Constructed Catchment and Storage Capacity for Charlotte Amalie, St. Thomas, 1926[a]

City Quarter	Unit Number	Proposed		Constructed	
		Catchment Sq. Ft.	Storage Gal.	Catchment Sq. Ft.	Storage Gal
Crown Prince's	1	43,500	354,000	43,500	385,875
	2	22,500	194,000	22,500	214,598
	3	60,000	559,000	62,000	610,875
Queen's	4	79,800	722,000	-[b]	-
King's	5	150,750	1,362,000	67,000	445,875
Total	5	356,550	3,191,000	194,500	1,657,223

[a]Source: Johnson, Water Supply for St. Thomas, p. 22.

[b]Not constructed.

were not only too shallow but also easily contaminated with brackish water because of their frequent location in beach areas. To alleviate these deficiencies, a relatively small public catchment and cistern were constructed to service the needs of Cruz Bay, the most populous settlement on St. John.

Historically, St. Croix has likewise been plagued with water supply constraints similar to those obtaining in her two sister Virgins to the North. During the Danish administration, the traditional small-scale sources were developed to service a growing population necessary to sustain the expanding agricultural economy based on cotton and sugar exports. The first public facilities were common wells which supplied in many instances brackish water. Inevitably demand exceeded supply and chronic shortages called for long-term solutions through public intervention.

The Navy Administration addressed itself to the situation. Following the recommendation of Commander Warfield, in the 1920's the Municipality of St. Croix purchased 115 acres of the Recovery Hill watershed.[35] Then a concrete dam was constructed along with a concrete-lined reservoir with a capacity of about 1,000,000 gallons. It was located near the lower property line at the edge of the city of Christiansted, the site of local government, on the northern sea coast. Since the water was not treated, however, most could be used only for

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[35] This section borrows heavily from Arthur F. Johnson, Water Supply for the Towns of Christiansted and Frederiksted, St. Croix, Virgin Islands of the United States, (Bureau of Rclamation, 1936).

sanitation purposes. This installation was later reconstructed and a slab roof erected over the larger portion of the basin forming a closed reservoir of 890,000 gallons. In addition to the catchment area provided by the roof, a concrete slab was laid on the hillside immediately to the east area creating a total catchment of 30,350 square feet. Two small reservoirs were added, one at Christiansted and the Creque reservoir near the only other major urban center, Frederiksted, stituated at the western extremity of St. Croix on the coast. These supplies proved inadequate, however, and within a decade the Muncipality was obliged to augment the cistern capacity of both towns.

Continuance of potable water shortage throughout the islands during the post-Warfield period prompted the Governor in 1936 to propose an ordinance which created a public water authority. This body composed of various cabinet officials was charged with insuring that several specific provisions relating to catchment-cistern systems in private dwellings were carried out. These provisions required all owners of tenantable houses, whether occupied or not, to install on their properties an adequate water supply. The regualtions stipulated that storage tanks or cisterns be of cement or metal construction and mosquito proof in accordance with existing sanitary codes. Furthermore, all such cisterns with cave gutters and down-spouts to shunt water from the roof surface to storage container had to be kept in repair.

Penalties were provided for infractions of the ordinance. Despite these rather stringent and clearly defined requirements, Johnson's study revealed that compliance was deficient:[36]

> "As many of the houses are inadequately provided with cave gutter, spouting and storage capacity, considerable hardship is imposed during the annual dry season and actual want occurs when, as frequently happens, a period of drought extends for several months. At such times cattle die of thirst and people go on short rations buying or borrowing water from more fortunate neighbors or public supplies. Sometimes importation of water supplies by ship has been necessarry."

At this time nearly half of the entire population of St. Croix was without facilities for obtaining regualr water supplies. Sixteen public wells were scattered throughout the town of Christiansted at convenient locations. Generally these wells provided a public supply for such private domestic purposes as washing, bathing, cooking, etc. The tap water was used for drinking only when rain water supplies were unavailable. In Frederiksted conditions controlling ground water supplies were more favorable because of the town's strategic position at the intersection of a large mountain watershed. The principal water supply for Frederiksted was the aforementioned Creque Reservoir which was formed by

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[36] Arthur F. Johnson, Water Supply of the Towns of Christiansted and Frederiksted, St. Croix, Virgin Islands of the United States, (Bureau of Reclamation, 1936), p. 7.

constructing a concrete arch dam 60 feet high across Creque Gut located 3 1/2 miles north of the town. In addition, a few private wells were supplemented by eight public wells. At all times, 44 percent of the entire Crucian population depended on these public facilities or obtained water from other individuals with private supplies. During the intense drought periods, this percentage approached 77 percent since only 33 percent of the people had sufficient supplies to last through the most severe short-falls.

By 1945, the potable water distribution system serving the urban area in Charlotte Amalie, St. Thomas, was supplied from two sources: rain water stored in municipal covered reservoirs, and the remainder barged in from Pureto Rico. With respect to the former, there were eleven paved areas to catch rainwater. They were located on the hillsides near the town with a total area of approximately 10 acres and a storage capacity of 3,350,000 gallons. These facilities provided a dependable average yield of about 22,000 gallons per day (8.05 million gallons per year).[37] Some of the larger catchment systems supplied water to limited areas of the city through piping networks connected to the storage tanks. However, people had to carry water from the other

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[37]Tippetts-Abbett-McCarthy-Statton, Inc. Potable Water Supply for St. Thomas, Virgin Islands, (San Juan, P. R.: November, 1958), p. 15.

smaller catchments which had no distribution lines. Although several of the reservoirs in town were connected to the distribution system, the water available from them was not circulated throughout the entire system, but was utilized instead for supplying street hydrants which were opened for public use twice weekly.

During the 1950's, existing water supply sources still proved to be inadequate. As an emergency measure, the U.S. Navy began, in 1955, to barge water on a regular basis from Puerto Rico to St. Thomas. The Virgin Islands Government took over the barging operation when it became evident that, if for some reason the barging were interrupted, a severe water crisis would develop. During 1957, thirty-six million gallons of water, approximately 62 percent of the total pumped into the distribution system, was hauled in by barge.[38] Finally when barged water became the principal source and mainstay of local supply during the early 1960's, a memorandum from the Chairman of the Committee of Interior and Insular Affairs of the U.S. Senate recommended a cheaper alternative and one more sensitive to domestic control:[39]

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[38] Tippets-Abbett-McCarthy-Stratton, Inc., Potable Water Supply for St. Thomas, Virgin Islands, (San Juan, P.R.: November, 1958), p. 15.

[39] Potable Water Problems, St. Thomas, Virgin Islands. Memorandum of the Chairman to the Members of the Committee on Interior and Insular Affairs, (Washington, D. C.: U. S. Government Printing Office, 1957), p. 4.

> Years of analysis of differing methods of producing fresh or potable water from the sea lead to the conclusion that distillation processes offer the best and most economical methods of converting sea water, which is readily available on St. Thomas, to potable supplies.

The first distillation plant in the Virgin Islands was installed on St. Thomas in 1962. It was manufactured by the firm of Aqua Chem with a capacity of 275,000 gallons per day. As a result, the potable water supply was significantly increased. To illustrate, in 1963 total water production from desalinization and barging was approximately 190,000,000 gallons, an increase of almost 80,000 over fiscal 1962.[40] The following year a new pumping and filtration plant was put into operation in conjunction with a new water main installed along the length of the city. This resulted in raising the water pressure to adequate levels to supply all urban sections below 150 feet elevation.

In 1966, a second distillation plant was added to the system. Manufactured by Westinghouse, it did not initially produce at its designed capacity of 1,000,000 gallons per day. Consequently, production for the years 1967-1968 was restricted because of repairs and revisions. As a result, substantial supplies had to be barged in from Puerto Rico to satisfy existing consumption. This external reliance was

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[40] Annual Report of the Governor of the Virgin Islands, 1963, (Washington, D. C.: U. S. Government Printing Office, 1963), p. 69.

due not only to the periodical shutdowns but also to the steadily increasing per capita consumption levels deriving from rapid tourist and manufacturing expansion. Nevertheless, (according to Table II) 1967 was a bellwether year in that for the first time the St. Thomas system supplied the major share of local requirements.[41]

In order to keep apace with this increasing water production, additional and enlarged storage capacity was required. Construction was begun in 1968 on two 10 1/2 million gallon reservoirs. In the same year, a third distillation plant was added to the water producing system. It was manufactured by Baldwin-Lima-Hamilton with a capacity of 2,500,000 gallons per day. By 1969, the total complex of three St. Thomas desalinization plants were producing triple the quantity of water of the first plant in full operation.[42] In another development, the Water and Power Authority in 1972 awarded Envirogenics Company a contract for construction of two identical distillation plants of 2,250,000 million gallons per day capacity, one on St. Thomas and one on St. Croix. Both were scheduled to be in service by mid-1974. However, neither was in operation at the close of that fiscal year. Presently, the potable water system on St. Thomas comprises

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[41] Data reported in H. E. McDowell & Associates and Alton A. Adams, Master Plan and Report, Potable Water System, East End St. Thomas, Virgin Islands, (1973), p. 4

[42] Annual Report of the Governor, 1969, p. 13.

TABLE II

Potable Water by Source, Virgin Islands, 1962-1972[a]

Year	Source of Supply (gallons)	
	Distillation	Barged
1962[b]	25,261,700	84,354,300
1963	113,684,800	75,914,600
1964	96,311,400	135,706,450
1965	75,900,000	172,000,000
1966	124,300,000	150,700,000
1967	272,697,770	80,262,420
1968	269,865,000	162,406,200
1969	357,928,000	169,008,000
1970	571,412,600	105,261,000
1971	706,222,000	26,114,000
1972	808,916,500	25,462,000

[a]Source: <u>Annual Reports of the Public Works Department of the Virgin Islands</u>, selected years.

[b]Period from February 28 to June 30, 1962.

40 million gallons of storage in steel tanks and 7 1/2 million gallons in concrete tanks.[43]

In St. Croix, in order to supplement the public wells and, by this time, the nine million gallon Creque Reservoir, water systems for the towns of Christiansted and Frederiksted were completed in 1951. Each of these systems drew its supplies from wells -- Christiansted from three wells in the valley of the Salt River, and Frederiksted from two wells in the lower valley of Jolly Hill Gut.[44] By the early 1960's potable water from Christiansted was drilled from five wells drilled in limestone along Salt River. The quantity of water pumped was about 100,000 gallons per day.[45] Potable water for Frederiksted was from three wells drilled in volcanic rock three-fourths of a mile north of the city. About 100,000 gallons per day was pumped from this well field, but much of the water was lost through leaky water mains.[46]

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[43]Rudolf Galiber, "Potable Water Distribution," address before the WRRC Conference: Augmenting the Virgin Islands Water Supply, (St. Thomas: Caribbean Research Institute, 1975).

[44]Tippetts-Abbett-McCarthy-Stratton, Inc., Potable Water Supply for St. Croix, Virgin Islands, (San Juan, P. R.), p. 1.

[45]P. E. Ward and D. G. Jordan, Water Resources of the Virgin Islands: A Preliminary Appraisal, (U. S. Geological Survey, Open-File Report, 1963), p. 16.

[46]Further more specific details are given in Donald G. Jordan, A Survey of Water Resources of St. Croix, Virgin Islands, (U. S. Geological Survey, Open-File Report, 1975), pp. 6-9.

During this period, practically all water used for human consumption was rain water which had been stored in cisterns. In most places this water was caught on the roofs of buildings and piped to a storage tank, but in some places concrete catchment basins had been constructed. Rural residents obtained water from more than 100 drilled wells, a few dug wells, two hillside catchments, and roof catchments. In addition, about 25 dug or drilled public wells individually served from a few to several hundred persons.

Construction of St. Croix's first distillation plant, manufactured by Stearn-Rogers, with 1,000,000 gallons per day capacity, began in October 1967, and went into commercial operation in May, 1968.[47] A 10 1/2 million gallon water reservoir was built near Christiansted and a second water storage tank, of like proportion, was erected at Kings Hill, the following year. A 1-million-gallon storage tank was completed near Frederiksted, and a second one erected on Recovery Hill. St. Croix's second distillation plant, manufactured by Envirogenics with a capacity of 2,250,000 million gallons per day, as noted above, is not yet operational.

By 1970, several improvements were made throughout the Crucian distribution system. These included the following: a line extension connecting the million gallon tank at Recovery Hill to the existing system in Frederiksted; the

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[47] Annual Report of the Governor, 1969, p. 74.

Kings Hill storage tank line extension from Kings Hill along Centerline Road providing service to homes along its route and also boosting the pressure toward Frederiksted; and a line extension at Campo Rico, Golden Rock, Whim, and Two Williams; a total of some 10,000 linear feet of 4 inch, 6 inch, 10 inch and 12 inch water lines and two additional wells.[48] The desalination plant, for fiscal 1970, produced 153,000,000 gallons of potable water. Another 158,000,000 gallons was obtained from well fields, while 14,000,000 gallons was barged from Puerto Rico.

Since 1971, the public industry has also relied upon private enterprises to supplement the potable water supply. From its in-house desalination plant, Harvey Aluminum (later Martin Marietta Co.) has contributed significantly to the total island supply. For example, Table III indicated that in 1972 Harvey's share was almost one third of total potable production. As the figures show, in recent years this proportion of private commercial production is falling, i.e. 24 percent in 1972. The data also indicate the sizable share of well water in St. Croix, unusual in comparison with St. Thomas, which has excluded distillation production in recent years.

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[48] Annual Report of the Governor, 1970, p. 94.

TABLE III

Sources of Water Production on St. Croix, 1970-1974[a]

Source	Time Period				
	1970[b]	1971[b]	1972[b]	1972/73[c]	1973/74[c]
Wells	145,161,137	192,394,664	245,750,800	241,195,580	239,682,940
WAPA	246,933,000	234,304,000	172,942,724	192,985,924	230,542,000
Barging	1,467,200	4,067,985	---	---	---
Harvey-Martin Marietta	---	3,218,800	131,751,893	188,117,665	175,248,800
Total	393,561,337	433,985,449	550,445,417	622,299,169	645,473,740

[a]Source: Records of Department of Public Works, Christiansted, St. Croix.

[b]Calendar year.

[c]Fiscal year.

St. John has, over the years, obtained domestic and municipal water supply from rain catchments, dug wells, and barge shipments from St. Thomas and Puerto Rico. A deep-well pump and a 10,000 gallon water tank are installed at Carolina, St. John, to augment the water supply. There is a 500,000 gallon steel storage tank and a 100,000 gallon concrete storage tank at Cruz Bay.[49] Recently, a new distribution system was completed which includes several thousand feet of 8" pipe and a pump station to deliver water to high levels.[50] There are no water production facilities under the Virgin Islands Water and Power Authority on St. John. There are a few of the old Danish wells in occasional use but mainly for stock water and construction purposes. In addition, Caneel Bay Plantation, a resort complex and the largest employer of the island; is served by a paved catchment with large cistern, roof catchments, and a small distillation plant.[51]

The present situation of water supply in the Territory can be summarized.[52] There are currently six major sources

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[49]Rudolf Galiber, "Potable Water Distribution," address before the WRRC Conference: Augmenting the Virgin Islands Water supply, (St. Thomas: Caribbean Research Institute, 1975).

[50]Ibid

[51]Oliver J. Cosner and Dean B. Bogart, Water in St. John, U. S. Virgin Islands, p. 5.

[52]This summary is drawn from Penn, Cassells, Adams, Population, Economic Activity, etc., pp. 6-7

of available water. First, sea water for fire fighting and sanitary flushing is used predominantly in the dense urban cores of the three main cities. Second, desalinated sea water is the major source for industrial consumption and also supplements urban residential demand. There are 4 desalting plants operating in St. Thomas and 2 in St. Croix. Third, rain water collected in private home cisterns is the primary domestic supply. Although public catchments still exist and collect water, they are not in use. Fourth, there are approximately 280 dams across the three islands. This supply is generally used for watering livestock. Fifth, the greatest amount of well capacity is in St. Croix (see Table III). These wells are both publicly and privately owned and they supply both residential and agricultural needs depending on their respective water quality. Sixth, wastewater recycling through treating sewage outflows, is primarily for agricultural usage and for ground water recharge to supplement well supplies. Finally, barging from Puerto Rico has been discontinued except during rare periods of extreme dysfunction in the desalination complex.[53]

Any attempt to quantify in broad strokes the current scope of the public water industry in the Virgin Islands demands some definitional distinctions and at least a preliminary discussion of short-comings in the data. First,

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[53]Such and emergency occurred in December, 1976, when all four St. Thomas distillation plants were down.

public or municipal water is restricted to all water consumed from WAPA desalination plants through the potable water distribution system plus the publicly owned wells in St. Croix. Such public water serves residential, commercial, and light industrial uses. On the other hand, agricultural and heavy industrial requirements are therefore excluded.

Concerning the data there are several deficiencies. First, much strategic information is simply unavailable. Second, it is exceedingly difficult to monitor actual residential consumption -- the major brunt of the municipal supply -- since much of this demand is satisfied by rainfall caught in the average cistern required by law.[54] Third, much distilled water passing through the archaic distribution system is lost through leakage and periodic breaks. Some of what is consumed however goes unaccounted for because of absent or faulty meters.[55] Despite these data limitations, recent estimates portray the following picture:[56]

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[54]See further problems of distinguishing between the residential versus commercial components of municipal water because of the large temporary tourist population, in Penn, Cassells, Adams, Population, Economic Activity, etc., p. 7.

[55]To illustrate with just one of the many estimating porblems, after a broken pipe is repaired and re-opened, there is a time lapse before the drained system refills. Yet the flow of air in front of the released water is metered as an actual water flow since the monitoring device cannot discriminate between air versus water flows.

[56]Penn, Cassells, Adams, Population, Economic Activity, etc. p. 8.

Presently, the total municipal consumption for the territory is approximately 4.55 million gallons per day. With 2.5 million gallons per day on St. Thomas, 2 million gallons per day St. Croix and 50,000 gallons per day on St. John. On St. Croix 700,000 gpd of the total consumed is supplied from wells.

The Virgin Islands Water and Power Authority has the capacity to produce a total of 7.25 mgpd. through its desalination plants 4 mgpd. on St. Thomas and 3.25 mgpd. on St. Croix. Water for St. John is barged to the island, stored and delivered by trucks to users. The Water and Power Authority which expects the consumption on St. Thomas to double within 3 1/2 years upon the completion of additional water line to outlying residential area, has planned to expand its capability to be able to produce on both St. Thomas and St. Croix an additional 7 1/2 mgpd. by 1977.

PART II

A COMPILATION OF AVAILABLE DATA AND RESEARCH REFERENCE SOURCES RELATING TO ALL ASPECTS OF DEMAND AND SUPPLY IN THE PUBLIC WATER INDUSTRY OF THE UNITED STATES VIRGIN ISLANDS

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Introduction

This document consists of two sections. The first section summarizes the various types of information that have been assembled to date. The second is an extended bibliography of research materials from which the above information was drawn. Cross-referencing from the type of information in Section I to the respective bibliographical source in Section II is readily accomplished because the data summary is clearly classified according to specific content headings. Also, the titles in the bibliography are specific and technical in nature, and are easily identified. Together both sections provide accessible working materials for the execution of the final and more analytical phases of the overall project.

Section I: Summary of the Available Data

This section briefly lists the types of information collected in topical form. These types are classified according to the following eight categories: geology, climate, supply sources, consumption patterns, production rates, cost estimates, institutional aspects, and legal aspects.

In most cases, except for topography, the listed material refers to all three Virgin Islands, and covers most extensively the recent period from 1960 to the present.

Types of Material

1. Geology:

   a. distinguishing size characteristics
   b. inter- and intra-island topography
      1) watersheds and basins
      2) steam flows
      3) ground water
      4) water quality and salt water intrusion

2. Climate:

   a. temperature and wind flows
   b. rainfall frequency
      1) seasonal variation
      2) inter- and intra-island distribution
      3) estimated runoff
   c. evapotranspiration

3. Supply Sources:

   a. wells private and public
   b. private cisterns (limited information)
   c. public catchment and storage systems, capacity and water quality
   d. natural reservoirs and dams
   e. distillation production, both public and private
   f. barged water from Puerto Rico
   g. wastewater reclamation feasibility and experiments
   h. locations of all of the above in detail (maps) including for all three islands the potable water distribution system

4. Consumption Patterns:

   a. demographic profiles plus projections to 2000
   b. population distribution
   c. past and projected demand rates distributed up to 2000:
      1) residential use
      2) agricultural use
      3) industrial use

5. Production Rates:

   a. for the natural sources: groundwater, precipitation, etc. through source of supply, i.e. wells, catchments, reservoirs, etc.
   b. for the desalination plants since their introduction in 1962

c. various discussions of production loss of public potable water through leakage, evaporation, etc. and various forms of deteriorating water quality in catchments, wells (intrusion), etc.
d. rates for private industrial production for heavy industry (Hess and Martin Marietta).

6. Cost Estimates:

a. cost estimates on all of the above under (5) plus barging from Puerto Rico including:
   1) distillation production in public and private sectors
   2) construction and maintenance of public catchment-storage systems and the distribution infrastructure (repairs and proposed extensions)
b. construction and maintenance of private domestic cistern systems
c. metering and monitoring
d. wastewater reclamation
e. transportation by truck from central storage tanks to outlying areas

7. Institutional Aspects:

a. organizational charts for WAPA and Public Works and the deposition of responsibilities between them
b. financial statements of these agencies, selected years
c. audits of their financial performance (Comptroller's Reports), selected years, with specific recommendations for improvement
d. cost allocation procedures between user payments and general tax revenues

8. Legal Aspects

a. all regulations pertaining to the construction, installation, and maintenance of private and public cisterns and catchments
b. pricing policy including provisions for free rates for the indigent residents of public housing projects
c. meter installation, reading and billing procedures
d. penalties of various kinds for non-compliance with any of these respective regulations.

Section II: Bibliography of Related Research

This compilation of reference material is selective but extensive. Generally, only those sources which have a direct bearing to water demand and supply in the Virgin Islands have been included. The majority of the approximately seventy-five references are housed, in whole or in part, in the Water Research Section of the Caribbean Research Institute library. Much of the most relevant detail in the other listed sources has been summarized in Part One: An Introduction to the Topography and Climatology of the United States Virgin Islands Including a Summary of the Evolution of the Public Water Industry.

In addition to these listed entries, there are of course many other supplemental materials of a more general nature concerning related water research done elsewhere, Caribbean archeology and topography, small island systems, and so on. These documents are also housed in the Caribbean Research Institute library in both the Water Research and the Socio-Economic Research Sections.

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