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CASE STUDY REPORT

VIRGIN ISLANDS MANGROVE LAGOON (1967 – 1984)

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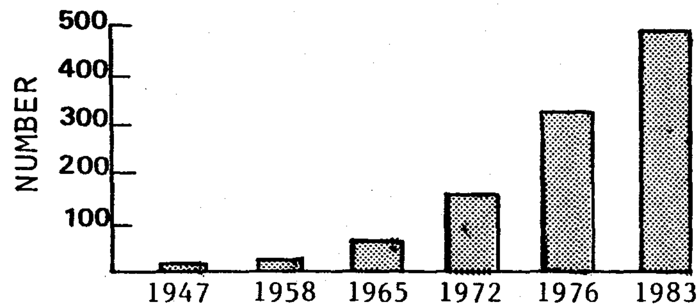
4.2 Virgin Islands Mangrove Lagoon (1967-1984)

4.2.1 Introduction

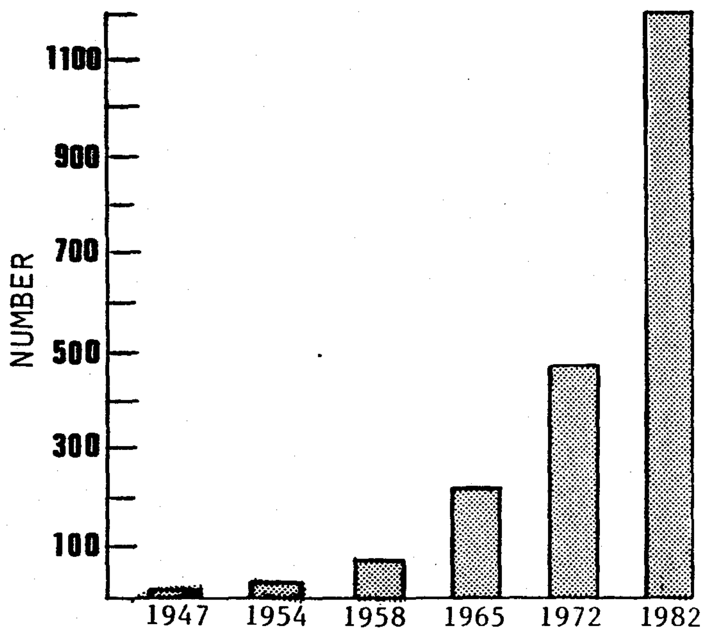
The southeastern coast of St. Thomas is endowed with a large, singularly attractive mangrove lagoon and bay of exceptional natural value. Its water, mangrove and grass bed systems traditionally provided a rich nursery area for fish and a productive habitat for benthic biota. Its mangrove fringed shores are a natural buffer against shore erosion, floods and hurricane waves. The coast's configuration provides a protective anchorage for boats and its adjoining hillsides are popular residential areas for Virgin Islanders. The area is filled with scenic contrasts, manglar islands, rocky cliffs, ponds and panoramic ridgelines. Its diverse complex of natural communities provides a recreational opportunity for Virgin Islanders. Yet these very attributes have attracted so many people in recent years that the same elements which first attracted them to the area are now being degraded.

Traditional uses of the "Mangrove Lagoon" (its official and generic names are the same) have included fishing, crabbing, clamming, the cutting of mangrove wood for charcoal and boat timbers, and serving as a protected anchorage for local boats, particularly as a hurricane refuge. Since the 1960's, however, development of the watershed and shores has proceeded virtually unchecked. Upland slopes, valleys and flood plains were bulldozed for two shopping centers, thousands of residential sites, and roads. Mangroves were cut and buried by backfill to create marinas, docks, a sewage treatment plant, roads and a racetrack. Coastal salt ponds were also filled. More people and more boats (Figure 3) created a need for new service facilities, i.e., more fresh water, more power, more roads, more parking, more docks, sewage treatment plants, and septic tanks. These, in turn, have reduced hillside vegetation and created higher residential and commercial densities resulting in more runoff, erosion and pollution. As pressures for development mounted, a series of environmental problems were created, and the Lagoon's traditional ecological values and functions were threatened.

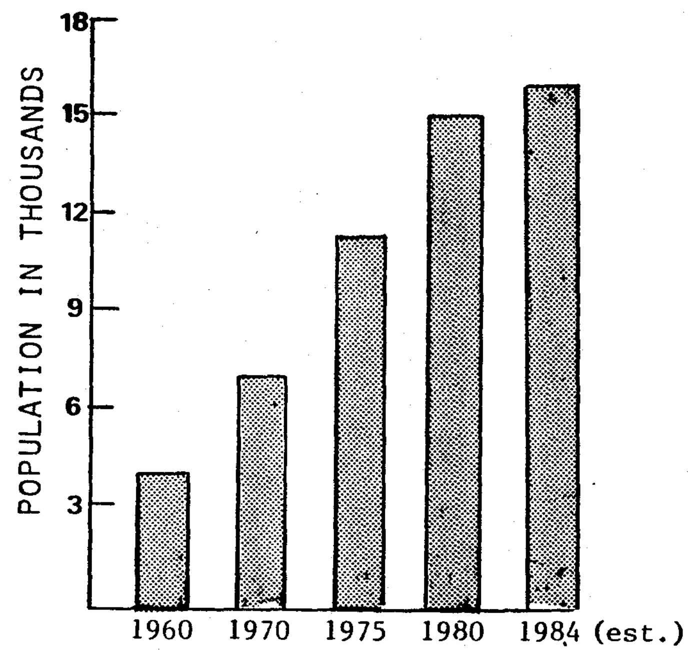
The following are some of the stresses and impacts currently impinging on or present in the "Mangrove Lagoon."



a. Boats in Mangrove Lagoon-Benner Bay.



b. Residential units in Mangrove Lagoon-Benner Bay.



c. Population in the Mangrove Lagoon, Benner Bay and watershed.

Figure 3. Trends in number of boats, residential units, and population in the Mangrove Lagoon-Benner Bay area. (Modified from Nichols and Towle, 1977b.)

- sewage pollution from anchored boats, sewage treatment plants, local septic tanks and shore establishments

- release of toxic trace metals from a municipal dump and boat yards, and local debris scattered around lagoon margins and watershed

- discharge of petroleum products, i.e., oil, gasoline and grease from boats, shore spillage, bilge discharge

- declining water quality, i.e., high turbidity, low transparency and low oxygen content, and rising indices of coliform bacteria

- growths of filamentous algae associated with high nutrient pollution loads

- sedimentation associated with storm runoff from the watershed and shoaling of the lagoon floor with formation of a black mud blanket

- disturbance of vital mangrove habitats by bulkheads, dumping and landfill to create dock space, berthing facilities and useable land

- loss of productive inshore clam and fishing grounds and reduction in vitality and diversity of bottom biota

- restriction of drainage with loss of flushing capacity and stagnation of backwaters favorable to mosquito breeding

- shoaling in the entrance channel which limits boat traffic and, in turn, marina use and economic viability.

Figure 4 schematically displays these current stresses and impacts in relation to contemporary lagoonal uses.

What is most notable, however, is not that the Mangrove Lagoon has deteriorated in an accelerated fashion but that this has happened within the context of a full spectrum of well-funded, well-intentioned, regulatory and control mechanisms, of planning, zoning, permitting, research and environmental assessment procedures, and after 1978 a formal Virgin Islands coastal zone management program designed and funded by the U.S. federal government.

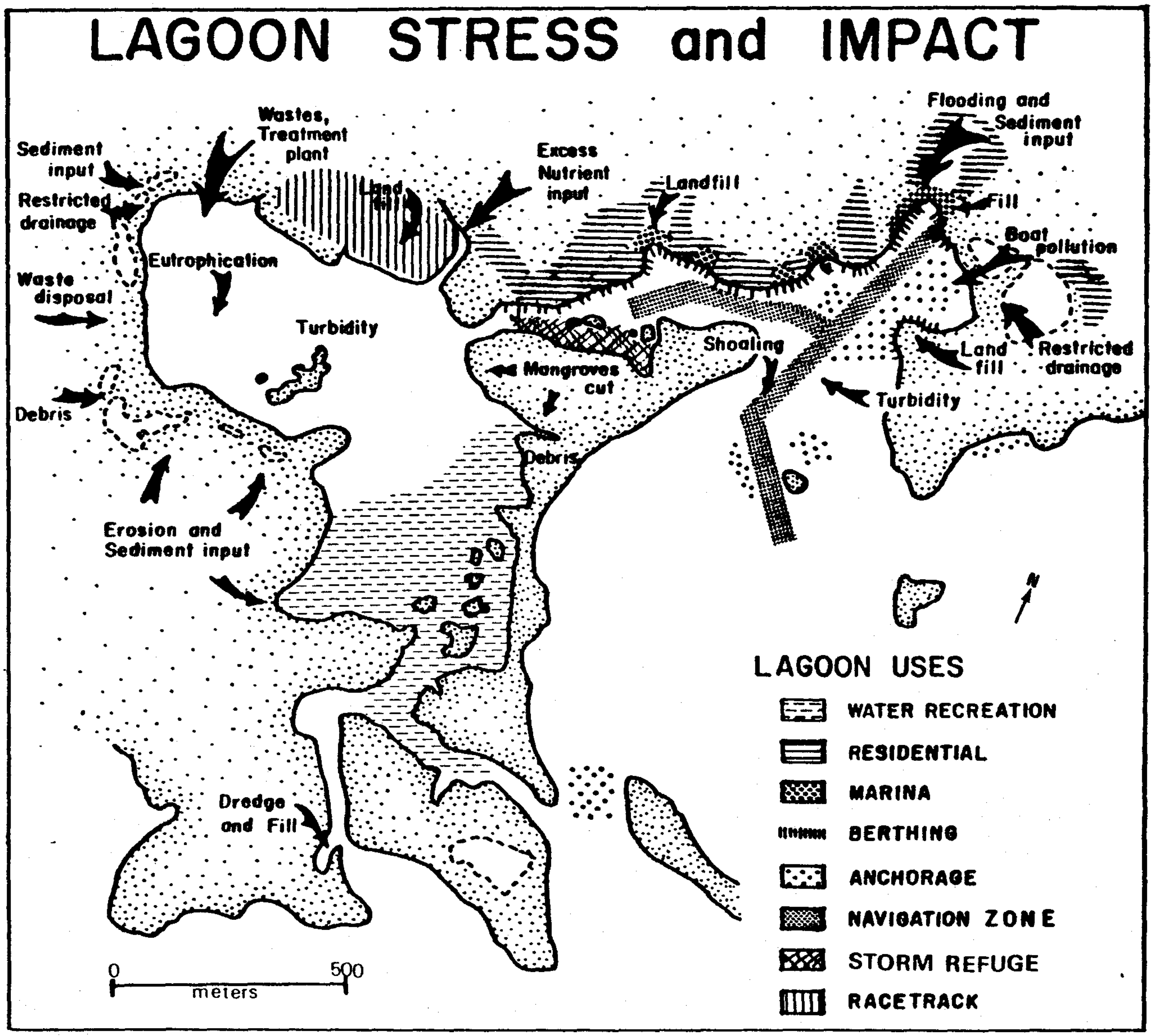


Figure 4. Schematic summary of stresses and impacts on the Mangrove Lagoon and Jersey Bay area, St. Thomas, 1983. (Modified from Nichols and Towle, 1977b.)

What went wrong? What can be learned from the labyrinth of emerging interactions between the users, the planners, the managers, the off-island exogenous factors and forces, and the natural ecosystem? It would appear that the management system was overwhelmed. Was it for internal or external reasons?

What follows is a fairly detailed description of the metamorphosis of an island lagoon/watershed system undergoing rapid change. It suggests that we can learn from experience, and it demonstrates that good intentions and local legislation, research and planning are not always enough to prevent the degradation of an island ecosystem in the face of externally generated and funded development pressures. It also stands as a kind of biography of an insular ecosystem that has inadvertently been pushed beyond its natural carrying capacity threshold into a new behavioral mode of a highly stressed, man-modified system requiring continous human management inputs of a costly and remedial nature.

4.2.2 Description of the Lagoon System

The Mangrove Lagoon with its contiguous passages, bays and backwaters forms a triangular estuarine system 2 km (1.2 miles) long and about 1.3 km (0.6 miles) wide overall. Because the shores are very irregular the average width is less than 0.5 km. The system lies in a northeast-southeast trending fault zone of sedimentary fill at the mouth of Turpentine Run, the largest perennial stream on St. Thomas. Mangrove fringed islands and shallow waters form an embayment in the coast which contrasts with the pattern of steep, rocky headlands and narrow sand or cobble beaches along the rest of the south coast of St. Thomas.

Together with Cas Cay and Patricia Cay, Bovoni Cay separates the Lagoon from Jersey Bay and the sea creating the quiet water necessary for extensive mangrove growth and the development of a safe harbor for small boats. Table 2 summarizes the geographic and hydrographic dimensions of the Mangrove Lagoon and Benner Bay.

Since the Lagoon is linked to the sea and to the watershed, contiguous upland drainage basins or "watersheds" and the waters of Jersey Bay are also considered. The standard geographic element is the ecosystem,

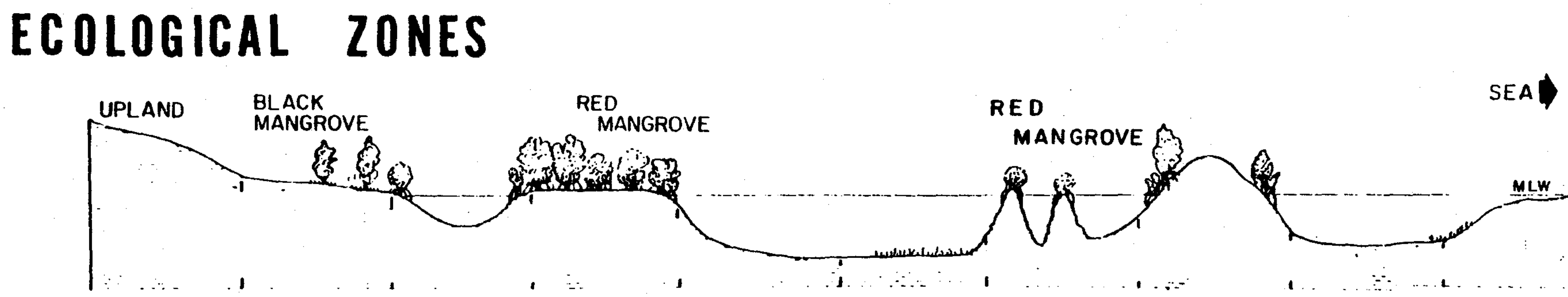
Table 2. Summary of geographic and hydrographic dimensions for the Mangrove Lagoon and Benner Bay systems. (Source: Nichols and Towle, 1977b.)

Parameter	Mangrove Lagoon (including passages)	Benner Bay
Length	1.6 km	0.4 km
Width	0.35 - 1.0 km	0.15 - 0.30 km
Water Area (Mean Low Water)	614,339 m^2	128,891 m^2
Water Area (Mean High Water)	809,471 m^2	135,607 m^2
Water Volume (below MLW)	805,675 m^3	160,394 m^3
Mean Depth Overall	1.3 m	1.3 m
Maximum Depth	3.2 m	2.2 m
Mean Tide Range	0.27 m	0.27 m
Tidal Prism	191,238 m^3	35,713 m^3
Shoreline Length (MLW)	1,374,641 m	13,201 m
Watersheds (total surface)	12.7 km^2	0.8 km^2

embracing all the biologic and physical components in the Lagoon which act together as an ecological unit; no single part of the system operates independently. The concept of a "coastal ecosystem" employed herein is that defined by Clark (1977) as including "... (1) a defined water basin (or series of interconnected basins), (2) all marginal (shoreline transition areas, and (3) all shoreland watersheds that drain into the coastal basin."

The lagoonal complex involves a series of ten ecological zones or units. These units are all linked by the flow of water and other human use. Table 3 summarizes attributes of these zones and their relative position with respect to each other, to water depth, and to distance seaward. Proceeding from greatest elevation, they are: the upland Tutu Valley area, a primary drainage basin called Turpentine Run with cactus and secondary scrub growth, the high tidal flats and salterns which are dominated by the black mangrove, the several ponds and inner lagoons which are edged by the red mangrove forest and swamp. There is also an open-water lagoon which contains turtle grass flats and manglar (barrier) cays. Between Bovoni Cay and Patricia Cay and between Patricia Cay and

Table 3. Ecological zones of the Mangrove Lagoon (from Nichols and Towle, 1977b).



ATTRIBUTES	DRAINAGE BASIN	HIGH TIDAL FLATS "SALTERNS"	PONDS & INNER LAGOONS	MANGROVE FOREST & SWAMP	OPEN WATER, LAGOON & BENNER BAY	GRASS BEDS (LAGOON) THALASSIA	MANGLAR CAYS	BARRIER ISLAND	PASSAGES, ENTRANCE CHANNELS	BACK REEF FLATS
AREA IN ACRES	3,334	10.7	14.34	49.9	183.0	11.0	4.5	15.3	14.8	10.4
WATER DEPTH OR ELEVATION	Range 0 to 260	Range 0.2 to 0.4	Range 0.1 to 0.3	Range 0 to 0.3	Mean 1.3	Mean 0.8	Range 0 to 0.3	Range 0.3 to 2.6	Range 0.2 to 3.2	Range 0.1 to 0.3
DRAINAGE OR FLUSHING	Intermittent	Partly Covered on Spring & Storm Tide	Slow	Red Mangrove. Covered with water most of year	Slow to Moderate	Slow to Moderate	Covered by Normal Tides	Rapid Drainage	Moderate	Rapid
SUBSTRATE OR BED SEDIMENT	Gravelly Clay Loam	Clay & Silt	Organic Muck	Peat	Mud, Sandy Mud, Muddy Sand	Muddy Sand Sandy Mud	Peat, Sandy Mud	Sand	Sand	Rubble, Sand
DISTINCTIVE ECOLOGICAL CHARACTER & FUNCTION	Dry Forest with Cactus, Secondary Shrub growth	Barren or Algal Covered	Bird and Wildlife Habitat	Forest Cover, Nutrient Production, Shore Stabilization	Plankton Habitat, Feeding and Nursery Area	Confinement, Nursery Habitat, Production, Nutrient Storage	Nutrient Production, Shore Stabilization, Sediment Trap	Storm Barrier, Sand Storage	Water Exchange, Feeding Area	Storm Barrier, Sediment Trap, Feeding Area

the mainland are entrance passages that lead to the back reef flats at the several "false entrances" (open but too shallow for boat traffic due to coral reefs). Much of the circulation for the Lagoon comes across these shallow reef systems in the form of wind driven currents.

The lagoon system acquires some of its water and much of its sediment from the upland watershed or drainage basin. Because the Lagoon is linked to the watershed, changes in topographic and flow characteristics of the watershed affect many functions in the Lagoon itself. Fresh water inflow governs the salinity of lagoon water which, in turn, affects the types of organisms in the Lagoon, their distribution and abundance. Additionally, the amount of sediment, nutrients, organic debris and some pollutants carried into the Lagoon is determined by stream runoff. These materials affect lagoon water quality, sedimentation rates, and plant production.

The drainage basin receives an average of about 40 inches of rainfall annually, but as much as eight inches has been recorded from a single 24 hour storm. Annually runoff amounts to only two to eight percent of the rainfall. The drainage system of the Mangrove Lagoon and Benner Bay consists of four sub-basins (Figure 5). Most stream channels are dry and carry only intermittent storm runoff. The Lagoon receives drainage conveyed through small guts or washes, through local culverts, and through a major stream channel--Turpentine Run. Most runoff in Turpentine Run infiltrates the soil and alluvium (Jordan and Cosner, 1973). Only major storm runoff, resulting from infrequent rainfalls totaling more than four inches, reaches the Lagoon as surface flow.

Intense development in the upper drainage basin of Turpentine Run (the Tutu area) has increased the potential for flash flooding into the Lagoon. By destroying the naturally absorptive soil and vegetation cover with construction of roadways, parking lots and roofs, and by lining stream beds with concrete, flood water from torrential rains is delivered to the Lagoon quickly (Nichols et al., 1979a). Most watershed sediment so supplied to the Bay is fine-grained silt and clay, and by remaining suspended in Bay waters the fines degrade water transparency.

Prior to 1968, flood drainage from Turpentine Run entered the La-

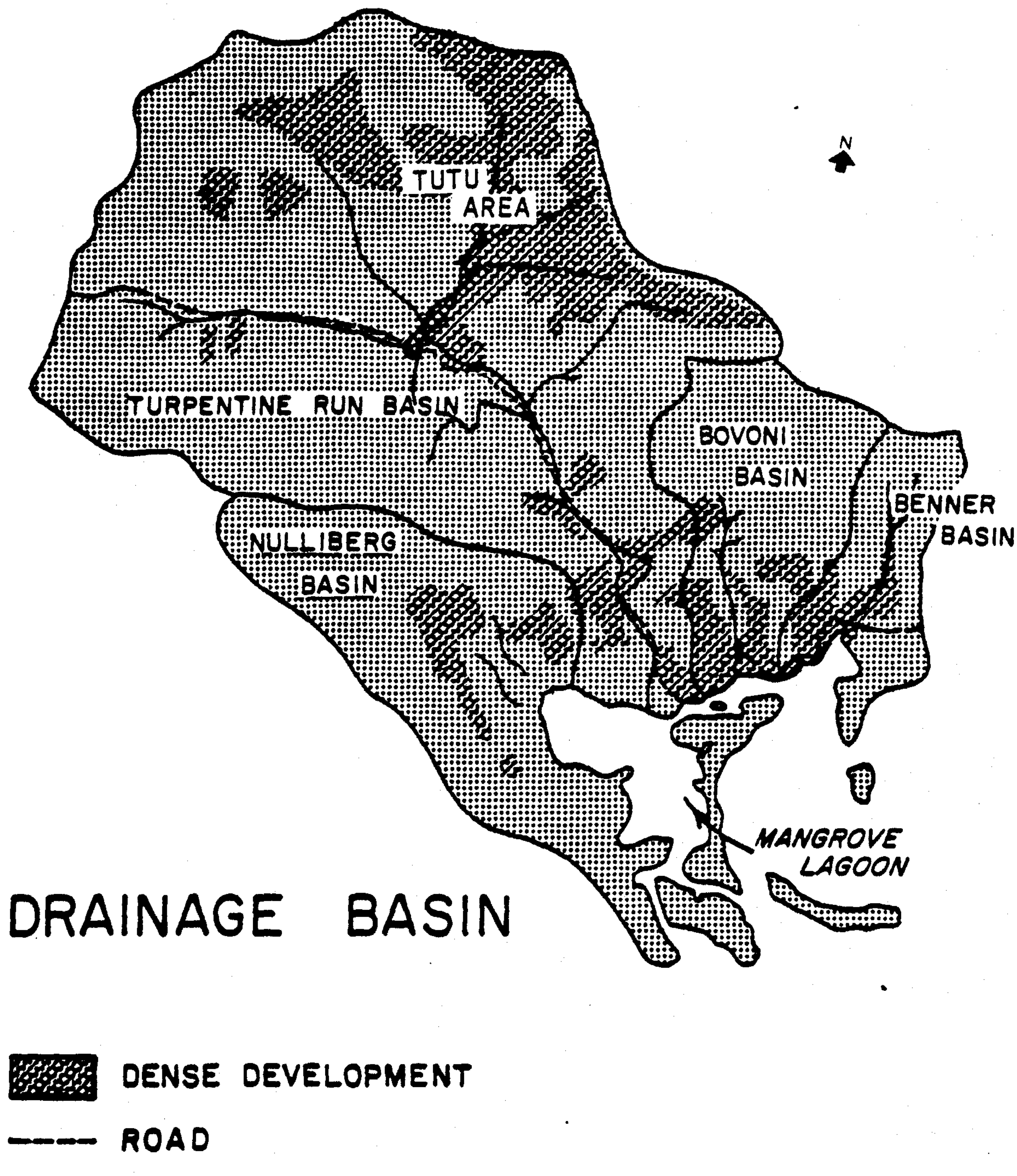


Figure 5. Drainage basins of the Mangrove Lagoon and Benner Bay, with areas of dense residence. (Source: Nichols and Towle, 1977b.)

goon through two or more vegetated distributary channels across an alluvia delta with mangroves. These shallow channels and the mangroves acted like a filter to cleanse the runoff of sediments and debris. When fill for a potential horse racetrack was dumped on the delta in 1968, drainage was short-circuited through a single channel directly to the Lagoon (Figure 6). Thus, the cleansing action of the distributaries was lost.

Some lagoonal circulation is wave driven. As waves enter Jersey Bay, they "feel bottom" and are refracted into gently curved patterns with crests more or less parallel to the bottom contours (Figure 7). Because of the narrowness of the west entrance channel and protection provided by Manglar Island and adjacent shoals, waves do not enter Benner Bay under normal conditions. Bovoni Cay excludes waves from the Mangrove Lagoon proper.

Although tidal forces are small compared to wind and wave transport over the reef, they are the most persistent force over the long term. They are also the main force during periods of light weather, a time when "worst case" conditions for exchange and flushing of pollutants develop.

4.2.3 Historical Development

The narrative begins in 1961 when the territory of the U.S. Virgin Islands entered into a dynamic period of rapid expansion and economic growth (stimulated almost exclusively by external factors) in three sectors--government operations, light manufacturing (assembly) exports, and tourism. In the case of tourism, growth rates were exponential, measured in tourist arrivals and accommodations. Massive U.S. government funding was also made available for public housing, roads, educational facilities, sewage treatment plants, health care and other human services. Additionally, U.S. tax incentives favored external investment in the Virgin Islands.

As a result, between 1960 and 1980 the population of the Virgin Islands doubled, and the employed labor force tripled. Electricity demand increased at an average of 20 percent per year. Thousands of new individual housing units were built. Public housing for 20,000 residents was constructed utilizing federal funding. A new 750 thousand barrel a

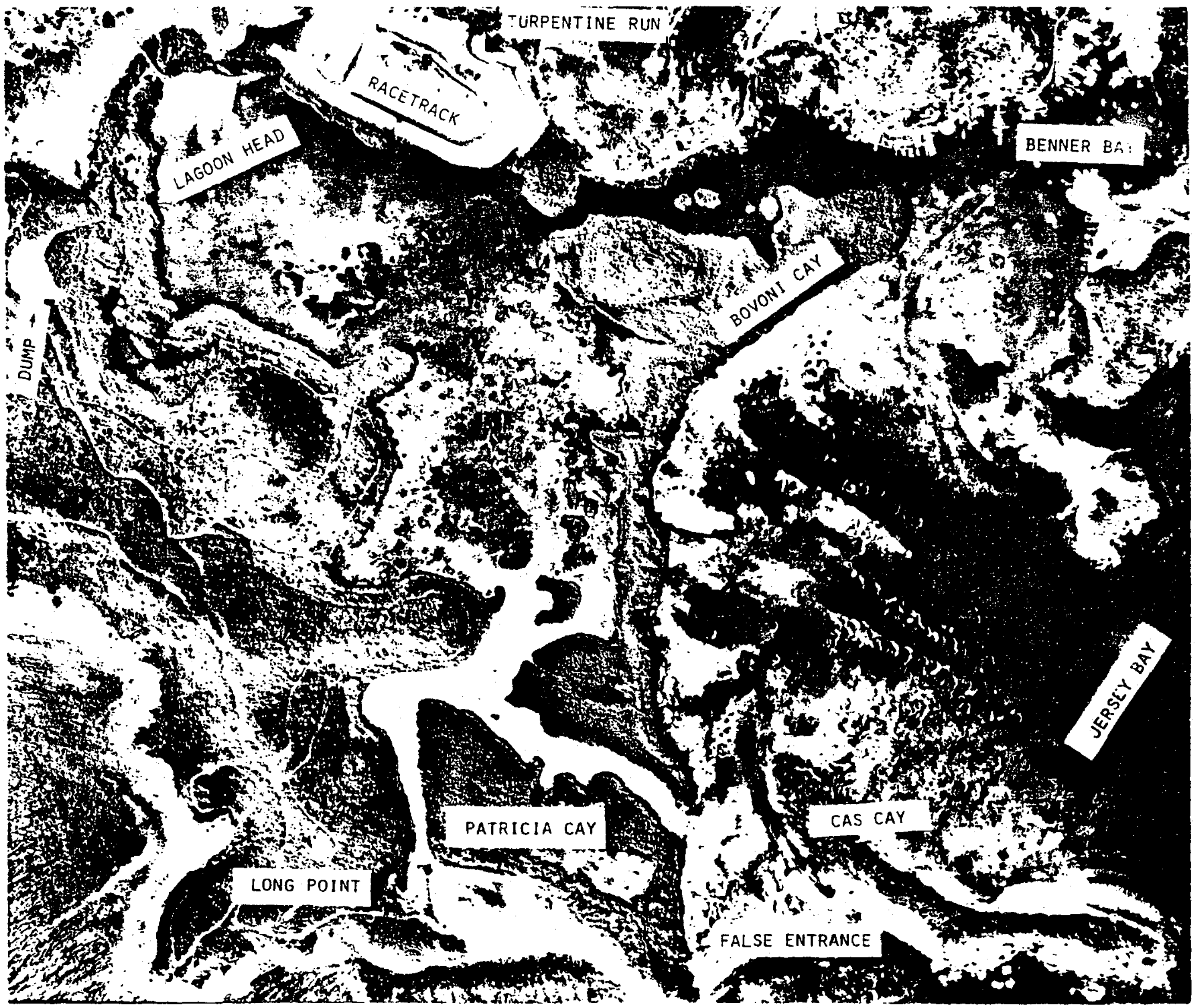


Figure 6. Aerial photograph of the Mangrove Lagoon and Benner Bay taken by the National Ocean Survey, November 23, 1972. (Source: Nichols and Towle, 1977b.)

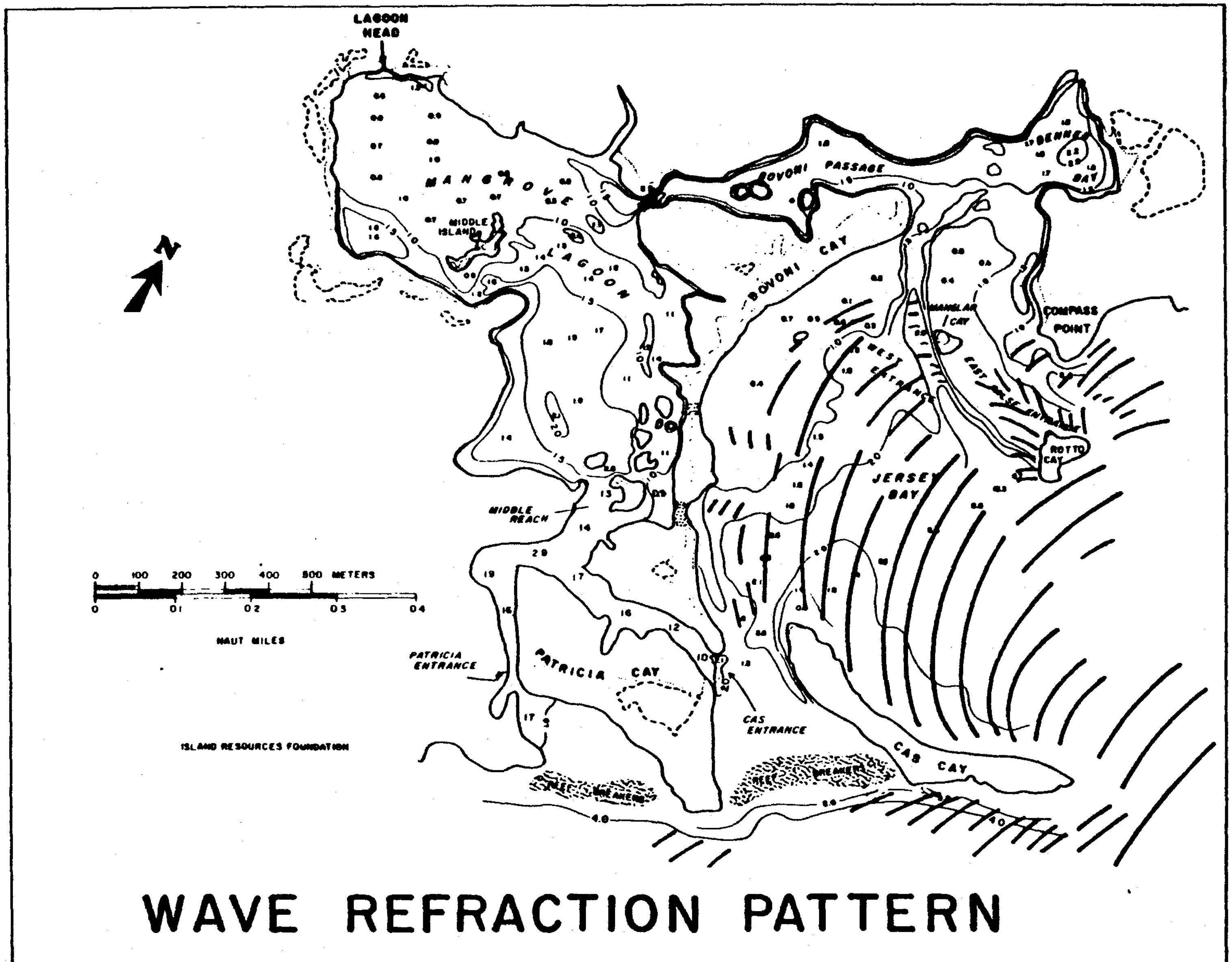


Figure 7. Wave refraction pattern for easterly swells reproduced from NOS aerial photographs of 1958 and 1974 (from Nichols and Towle, 1977b).

day oil refinery was sited on St. Croix (one of the three major islands within the territory of the U.S. Virgin Islands), adjacent to a new bauxite processing plant. Most standard indices for the Virgin Islands' economy had literally taken off, and the territory became increasingly dependent upon the mainland. As McElroy and Albuquerque (1983) have noted, "... the tourism base became pervasive ..., new ties were forged with national travel, financial, and transport interests..., federal social service and regulatory programs were institutionalized... [and] manufacturing activity (petroleum and aluminum refining) tied the territory inextricably into the global energy and raw materials markets." Although attenuated by the mild world-wide economic recession of the early 1970's, the process of accelerated growth has been sustained at only a slightly reduced level through the present time.

Sometime in 1967 the Governor of the Virgin Islands determined that the existing St. Thomas airport at Lindbergh Bay, on the island's southern coast near to the capital of Charlotte Amalie but removed from most major beaches and resort hotels, was unsafe and unsatisfactory and that a new international airport that could accommodate larger jet aircraft should be constructed at some alternative location. Engineering studies by off-island firms recommended that a new airport be constructed on the south shore of the Mangrove Lagoon on the easterly end of St. Thomas' shoreline. This would be accomplished by leveling Patricia and Cas Cays and Long Point and filling in intermediate reefs and the false entrances to build a runway which would have a more or less east-west axis, extending into 50 feet of water in Stalley Bay (Figure 8). It was a major engineering undertaking.

At the time no attempt had been made to assess the environmental impact of the proposed jet airport construction, and a bitter controversy in the community emerged which lasted the better part of two years. The resulting public debate evolved into rancorous polarization between the so-called growth vs. no-growth factions, between the environmental purists and the developers concerned with jobs, the economy, and human resource development.

Local opposition to the proposed airport resulted in the letting of

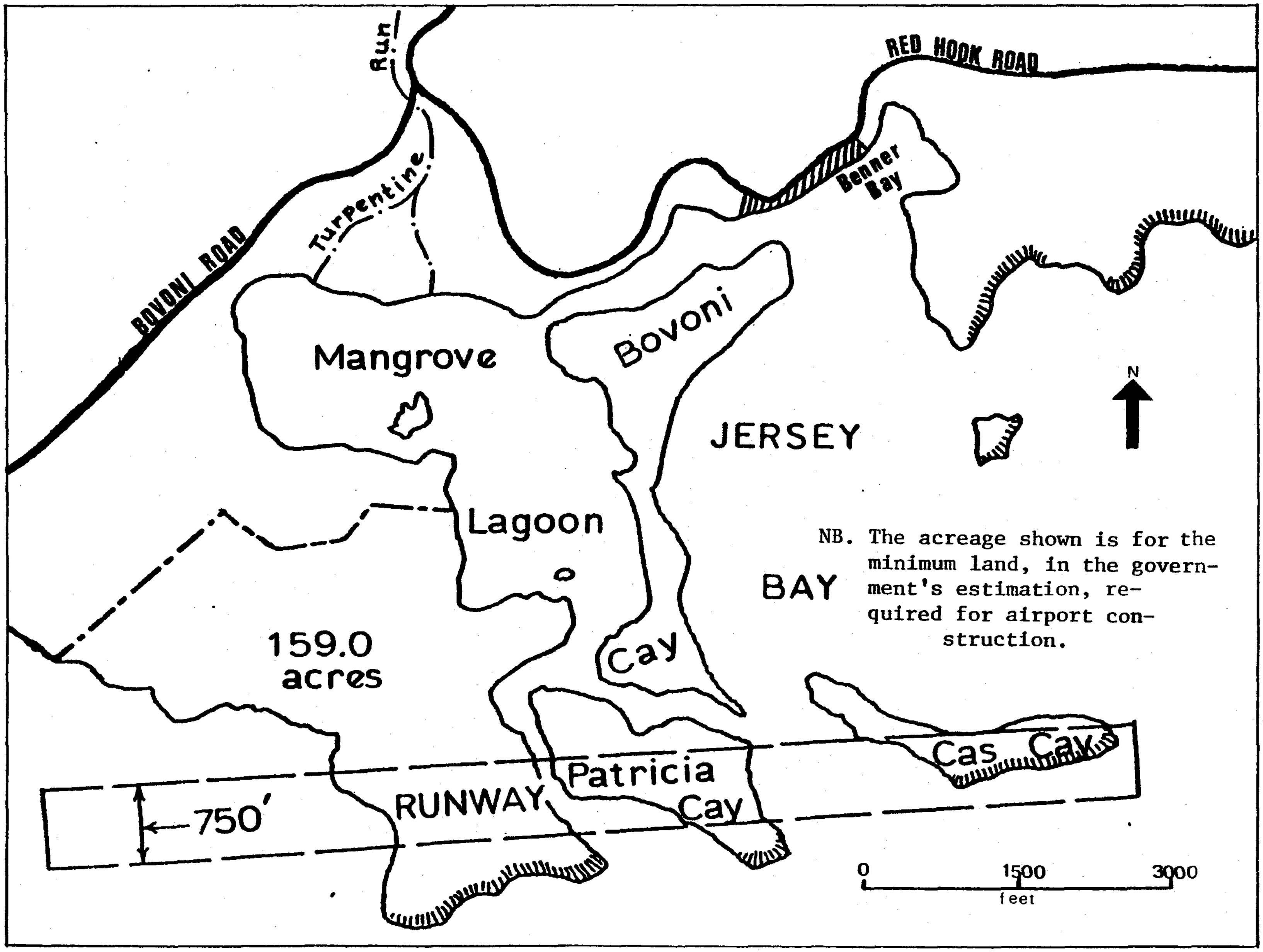


Figure 8. Mangrove Lagoon runway orientation for proposed St. Thomas jet airport, 1968. (Source: Tabb and Michel, 1968.)

a contract by the Governor's Office to the University of Miami in February of 1968 for a preliminary environmental assessment which resulted in a survey of the floral, faunal and hydrographic features of the Mangrove Lagoon. The consultants' report (Tabb and Michel, 1968) can be summarized as follows.

1) Turbidity from the silty clay component in the hill masses scheduled to be excavated and used for runway site fill would affect the entire bay area and, if prolonged, could have serious ecological consequences.

2) The construction of the airport would require paving over massive portions of the adjacent hillside areas, resulting in accelerated freshwater runoff in times of heavy rainfall, which would further aggravate pollution problems and result in nutrient enrichment (including sewage).

3) High water clarity and the natural seawater circulation were absolutely vital to the continued biological well-being of the Bay.

4) To conclude that conditions within the Bays might be improved by the addition of nutrient materials such as sewage was an unwise assumption.

5) The circulation pattern of the Mangrove Lagoon and the western part of Jersey Bay was dominated by the water transport induced by breakers on the shoals between the mainland and Patricia Cay and Patricia and Cas Cays. Transport from these breakers flows into Jersey Bay and the Mangrove Lagoon, overcoming the normal tidal flows and owing its existence to a rare combination of topography and wave characteristics coupled with a diurnal tide of a very small amplitude.

It is understandable that the Virgin Islands Governor's Office was unhappy with this report. An effort was made to seek a technological solution to the problem posed by the closure of circulation along Patricia and Cas Cays by the proposed airport project. An engineering consultant suggested the possibility of establishing an artificial wave run-up ramp and empondment on the seaward side of the projected runway, with a tunnel or sluiceway to be constructed under the airport runway itself. Such a scheme would <u>theoretically</u> maintain the pattern of water flow into the Lagoon and thereby maintain the normal circulation regime within the Lagoon itself (Michel, 1970).

At the same time, as the public debate continued, a worried voice was heard from a new direction, namely, from the island of St. John which lies immediately to the east of St. Thomas and directly under the path of the projected take-off patterns for the larger jets which would use any new airport at the Mangrove Lagoon. The U.S. National Park on St. John and a luxury resort hotel at Caneel Bay, St. John, were uneasy and quietly requested a U.S. Department of Interior, Fish and Wildlife Service study team to visit the Lagoon to provide further documentation on its ecological value.

The study team reported that "the Mangrove Lagoon is easily the most significant [mangrove] area remaining and is, in fact, very near the only stand of appreciable size that remains in the American Virgin Islands." They also found that "the Mangrove Lagoon is in fact the major remaining habitat in the northern U.S. Virgin Islands for about twenty species of herons, egrets, and other waterbirds and an equal number of wintering and migratory species." The U.S. Fish and Wildlife Survey experts expressed concern for the loss of habitat for waterbirds that live on Cas Cay and the adjoining waters of the Mangrove Lagoon, noting that encroachment on their habitat had already brought the population of many of these birds to extremely low levels (McNulty et al., 1968).

The administration was sufficiently confident with its position on building an airport in the Mangrove Lagoon that it purchased the land at Long Point, the focal point of the proposed facility. It also established a Port Authority so that it would be in a position to build and manage the new airport. However, the Governor was to discover that it was easier to decide to build a new airport than to find the money to construct it. During the ensuing, rather extended, delay yet another study of the Mangrove Lagoon, involving nine months of field work, was carried out by the research arm of the local college, the Caribbean Research Institute. The final report from this survey (Grigg et al., 1971) more or less coincided with a year long down-turn in tourist air arrivals and with acknowledgment by the administration that it had not been able to identify the necessary funds for airport construction.

The environmentalists and most residents of the Lagoon area were elated, assuming the Mangrove Lagoon was now out of "danger" since no new airport would be located there. But the government purchase of a key parcel of land at the Lagoon was a harbinger of other things to come --other incremental kinds of change and new pressures to "use" the now government-owned land in the Lagoon, if not for an airport then for whatever was convenient. Further, the territory-wide accelerated growth pattern, especially for the island of St. Thomas, was rapidly subsuming the Mangrove Lagoon and its watershed. Local planning, resource management, and environmental protection agencies were simply overwhelmed by the process of change. They were unable to deal with the pace and magnitude of growth, landscape alteration, and resultant environmental impacts generated by outside, off-island factors and funding.

Between 1970 and 1971 the number of boats in the Lagoon had doubled, and a new full service marina (Antilles Yachting Services) and three new bare-boat chartering operations had started up in the Benner Bay area, with construction just beginning at another marina at Compass Point. At the northern end of the Lagoon, a fair-sized residential community was developing, serviced by a 70,000 gallon-per-day sewage treatment plant operated by the Virgin Islands Public Works Department, with its allegedly treated effluent draining into "polishing" ponds near the Lagoon's edge. At the other end of the watershed, in the Tutu Valley area, a massive residential and commercial building boom was under way. The population of the drainage basin, which had been about 4,000 in 1960, had doubled by 1971. No one foresaw that it would almost double again by 1980, reaching 15,000 persons (nearly one-third the population of St. Thomas). This substantial growth would also eventually spur demand for several new sewage treatment plants (funded largely by the U.S. government) and thousands of septic tank installations in both the coastal and more remote watershed housing units and smaller commercial establishments.

Local environmental agencies had been concerned for some time about the problem of how to handle domestic and commercial sewage and waste water from burgeoning new "point sources" in the Lagoon watershed area.

Signals from the Washington-based federal agency concerned with territorial "sewage problems" favored a "treatment" instead of a "disposal" strategy. Unfortunately, the former strategy was inappropriate for island systems. Therefore, instead of opting for a low-cost ocean outfall disposal strategy (appropriate for offshore islands) for raw macerated sewage, local government authorities were forced to accept the federally "approved," standard continentally based approach of a fairly sophisticated system of complex aerobic/ mechanical sewage treatment plants, which are costly and energy intensive. Unfortunately, isolated, upland units require polishing ponds which use up limited land area, and larger "downstream" coastal treatment facilities still require short ocean outfalls for final disposal of the partially treated effluent.

Most of the subsequently built sewage treatment plant systems were not designed for tropical environments, rarely performing to design specifications and with a fairly high rate of breakdown. Furthermore, they require a high degree of operator skill if they are to be maintained and remain functional. As a consequence of periodic, often extended electrical power outages, a not uncommon phenomenon in island areas, raw untreated sewage often passes directly into associated polishing ponds or the coastal littoral environment.

Many of these problems were anticipated locally, but because the external funding sources pressed for use of standard continental criteria and preferred technology, the island got what it did not need --a high cost, high technology, breakdown prone, decentralized management nightmare of a system. The Virgin Islands could and probably should have opted for the World Health Organization (WHO) strategy which encourages island areas to avoid elaborate treatment systems and use well designed, long ocean outfalls for disposing of macerated and chlorinated raw sewage, preferably below the coastal thermocline (as, for example, in the case of the Cook Islands [Raratonga], Western Samoa [Apia], and Papua New Guinea [Lae]).

The Virgin Islands did not, however, choose to reject the "inappropriate" sewage treatment strategies imposed from outside (to do so would have reduced funding levels), and the Mangrove Lagoon watershed was to eventually have a total of five government operated systems--all disaster prone and difficult, if not impossible, to run efficiently.

In the meanwhile, within the Mangrove Lagoon itself (more than half of which was bounded by privately owned land), development activities were expanding, stimulated by various U.S. (off-island) tax policies favoring "charter boat" operations. By 1975, Antilles Yachting Services, a large marina operation based in the Lagoon at Benner Bay, applied for a permit for expanded facilities. The environmental assessment report accompanying the permit application emphasized that because there were so many other large-scale pollutants entering the Lagoon area from the watershed runoff and from the malfunctional, government-operated sewage treatment plant at Bovoni and from the government's solid waste disposal facility at Long Point, the pollution contribution from their own modest proposal of a few docks and a little bulkheading was very small by comparison and would not make a substantial difference (Insular Environments, 1975b). They were in fact saying, "Why single us out?" The implication was that the larger pollution sources in the area, resulting from ongoing government activity, should be dealt with first in coping with the general deterioration of the ecosystem.

But even as these events were occurring, there seemed to be new hope for the Lagoon from a different direction. Stimulated by the passage of the federal Coastal Zone Management Act of 1972, the local territorial government elected in 1974 to apply for the necessary planning grants to implement a Virgin Islands Coastal Zone Management Program. Under the aegis of the local Planning Office, a team was assembled and contracts let for specialized planning studies. The first of these, completed in 1975 (Towle, Grigg, Rainey et al., 1976), suggested that the "Mangrove Lagoon" be considered as an "area of particular concern" (APC).

By June of 1977 the Virgin Islands had completed its preliminary Coastal Zone Management Program Plan (VI Government Planning Office, 1977) which, after extensive public hearings and extended legislative debate, was approved in October 1978. The program consolidated and centralized the local permitting process for development projects, officially identified so-called "areas of particular concern" (including the Mangrove Lagoon), laid out the requirements for more elaborate environmental impact review documents to accompany permit applications for development activities, and provided criteria for restricting development in the coastal zone to water-dependent uses. Once the planning phase was completed, the administration of the program was turned over to the Virgin Islands' environmental agency, the Department of Conservation and Cultural Affairs (DCCA).

Many observers believed that with the advent of the Coastal Zone Management (CZM) Program, piecemeal development and mismanagement of the Lagoon watershed would be a thing of the past. The future of the ecosystem, however, remained at risk without remedial action to reduce pollution loading.

The U.S. Environmental Protection Agency (EPA) (through the Virgin Islands Department of Conservation and Cultural Affairs) funded two studies to address the problem of pollution loading (Nichols et al., 1979a and 1979b), but neither had any observable effect on either the expanding operation of the solid waste disposal facility or on the increasing volume of sewage and nutrients discharged into the watershed by the government-operated sewage treatment plants. These plants continued to be hydraulically overloaded and to malfunction and, in some cases, to not function at all for extended periods.

Finally, the Department of Public Works, which was officially charged with responsibility for managing both the solid waste disposal site at the Lagoon head and the five sewage treatment plants in the watershed (at that time), continued to have problems. The Department was hard pressed to find man-power, funds, and facilities to address the dramatic increase in solid waste generated on St. Thomas. Volumes rose from 100 tons per day in 1971 to over 150 tons per day in 1981 and up to 200 tons per day by 1984. The burdens imposed by the continual operation of sewage plants running at 120 to 150 percent capacity and by the frequent power outages due to mechanical failures at the power plant also proved difficult. Furthermore, because local hotels were required under the Virgin Islands Environmental Protection Act to install package sewage treatment plants, the Public Works Department was continually training sewage plant operators, only to lose them to the private sector.

Lastly, it must be remembered that the Mangrove Lagoon was only one of many stressed areas in the Virgin Islands through this entire rapid growth period, causing the agencies involved to divide their interests, forces, and finances between the three major islands of St. Thomas, St. Croix, and St. John.

The foregoing discussion presents the context for the next series of impacts on the Lagoon which brings the current case study to what we call the remedial phase. In the early 1980's, the territorial government obtained funding for a new hospital to be located on the outskirts of the capital city of Charlotte Amalie, St. Thomas. The site was then occupied by the island's only horse racetrack, a very popular, heavily used facility for local racing enthusiasts. Because time was of the essence in commencing construction of the hospital, a quick decision was made by government to move the racetrack to the Lagoon. The reasons appeared sound: the government owned the land (which made it convenient) and, further, there was a partially completed racetrack there already. It had been started by the Department of Public Works in 1968 in the mangrove wetlands at the lower end of Turpentine Run, but terminated because the local government had failed to secure necessary federal permits.

The government's hastily assembled environmental assessment report, accompanying its coastal zone permit application in late 1980 for siting the racetrack in the Lagoon area, argued that it was Public Works Department's sewage treatment plant, immediately to the west of the racetrack site, that was causing all the problems in the Lagoon. The only irreversible environmental effect of the racetrack would be to diminish the area available for nesting birds. The Coastal Zone Commission granted the permit in early 1981. Public confidence in the efficacy of the Virgin Islands CZM permitting process was not enhanced.

It is ironic that just two months after the Coastal Zone Commission permit was issued for the racetrack, the senior planner of the Division of Coastal Zone Management completed and circulated for review his very detailed "management plan for the St. Thomas Mangrove Lagoon area of particular concern" (Teytaud, 1981). The plan was too late to have any effect, too complex for efficient application, and too removed from prevailing uses and management requirements to enjoy acceptance as a workable plan of action or for controls.

As water quality continued to decline and shoaling accelerated, DCCA came under increasing pressure from a newly formed, private sector Benner Bay/Lagoon Marine Industry Association and others to take more direct action to reduce Lagoon pollution loading and also to permit a deepening of the access channel by dredging. DCCA turned to the U.S. Army Corps of Engineers District in Jacksonville, Florida, with a request to study the feasibility of improving the flushing of the Lagoon. Proposed modifications included widening and deepening the Lagoon channel to Benner Bay and dredging a turning basin at the end of the Bay. The Corps responded favorably and promptly launched a preliminary reconnaissance survey. Their September 1982 report (U.S. Army Corps of Engineers, 1982) documented approximately 400 boats docked in the Bay, the majority of them in excess of 28 feet in length. To quote the report:

> Benner Bay is one of the three major harbors in St. Thomas. It provides docking and anchorage for a large portion of the charter sailboats in the islands and, in times of severe weather, serves as a vital harbor of refuge for many additional boats. The bay also houses five commercial marinas and one of the few boat-hauling and complete service repair facilities in the Virgin Islands. Since a large percent of the boats in the islands have drafts in excess of five feet, shoaling in the bay has greatly curtailed its usefulness as an anchorage both in emergencies and on a long-term basis. In addition, economic growth of the existing marine-related businesses in the area has suffered from the inability of deeper draft vessels to enter the bay.... Shoaling in the bay is also suspected to have contributed to the environmental degradation of the area by decreasing the flushing rate of the bay and the adjacent mangrove lagoon.

The Corps estimated that 45,000 cubic yards of material would need to be excavated, costing $160,000 for final planning and engineering studies plus an additional $495,000 for dredging and construction costs, plus incidentals, for a total of $655,000. It would take two years, however, just to complete the detailed project plan. The "remedial action" phase of Lagoon management was fast approaching.

The local marina operators found two years to be somewhat long for simply a planning phase and opted to do it themselves. The idea was, however, expanded to include an additional dredged area for ninety new boat slips, but the permit application to the Government was rejected, in part because of rising concern within DCCA about the number of moored and docked live-aboard boats used as residences. The agency believed that live-aboard boats were contributing significantly to the growing pollution problem in the Lagoon. Concern was laid to rest, however, in 1983, when an EPA funded study of vessel wastes in the territory demonstrated that while the Lagoon's boat population had risen in one year from 400 to 481 vessels, only 81 were live-aboards. Furthermore, the aggregate Biological Oxygen Demand (BOD) loading from all boats was only 8.6 lb/day, while at the Lagoon head, the combined loading of the sewage treatment plant and Turpentine Run effluents was 455 lb/day, or 98 percent of the problem (Wernicke and Towle, 1983).

With few options left open, and with public pressure mounting concerning both the public "dump" and sewage pollution at the Lagoon head, the government was forced to take action. It elected (with U.S. federal funding) to "eliminate" the dump by building a "high-tech" 350 tons per day solid waste incinerator/energy recovery plant (to make fresh water by seawater desalination) and elected to eliminate the "sewage" problem by building yet another high technology, centralized sewage treatment system (replacing all existing smaller plants which would be abandoned). The total estimated cost is 25 million dollars. The two proposed facilities are to be located at the Lagoon head shoreline (the old "dump site"), on the land previously purchased by the government for the aborted jet airport (Virgin Islands Planning Office, 1983).

As for the Mangrove Lagoon, its days are clearly numbered, and in one--perhaps two--decades it will have more facilities than fish, more boats than birds, and more modifications than mangroves, requiring ever more costly pollution control and continuing remedial measures (like dredging) to do what nature once did for free.

4.2.4 Retrospective Conclusions

In the first place, there was a conceptual failure by almost everyone to perceive the Lagoon and its associated watershed as a system of connected and related parts (some more critical than others). This resulted in a sequence of structural design failures in virtually every management sector or agency concerned with the Lagoon "sink" at the lower end of the watershed.

For example, the natural scientists who produced the approximately 20 research reports, monitoring documents, and development impact assessment studies between 1968 and 1983, with only two partial exceptions, failed to address the totality of the ecosystem, focusing only on the "effects" manifested in the Lagoon. The Mangrove Lagoon without its watershed may have been a useful and convenient study framework but it was not a satisfactory resource management model.

As a consequence, there was a tendency to measure and count the wrong things and not to quantify others. In studies of the Mangrove Lagoon there were elaborate scientific measurements and quantification of waves, currents and fisheries, of fecal coliform and other water quality parameters, and of the distribution of benthic and pelagic organisms, sea grasses, algae, and mangroves. But it might have been more useful to count fewer fish and algae, and to allocate more time and effort to count the number of site development permits, septic tanks, and housing units, and to measure periodically the devegetated areas in the uplands, as well as look at things like commercial effluents, stream flow and sediment loads in Turpentine Run. An assessment of the driving variables and trends in the whole system would have been more useful than just measuring their impacts on the aquatic system at the lower end of the watershed.

Even with this expanded focus, the task of data analysis leading to a determination of significance and to implications for management would have remained at risk because natural scientists are not accustomed to, skilled at, or comfortable interpreting these kinds of data. A team effort involving planners, resource management technicans, and natural and social scientists was required, but the terms of reference for most studies rarely encouraged or even permitted such an approach.

Both the planning and management systems failed to conceptualize the ecosystem as a "watershed unit" and therefore proceeded over the years to look at the phenomenon of growth in the area through an artificial framework of "census enumeration districts" and zoning districts and codes designed in 1970 but never modified in the face of emerging concentration and density factors in the "Turpentine Run/Mangrove Lagoon ecosystem."

In any event, just the existence of a central, physical or town planning unit (whatever it is called) can give all concerned a false sense of security. This problem is especially awkward when dealing with coastal and marine matters in developing island areas, largely because planning units seldom have staff competent to adddress the complex question of coastal resource planning. This situation is especially bothersome for insular areas undertaking more intensive strategies to develop coastal and marine resources.

As in the case of Rodney Bay in St. Lucia (see Section 4.1), there were also systemic failures in the transition of the Virgin Islands Mangrove Lagoon and its watershed from a low-cost viable natural system to a pollution prone area requiring high-cost engineering interventions to maintain its "utility" to residents and users. Units of the local resource management system (planning, zoning, environmental control, waste disposal, land use, and coastal zone management) were completely overwhelmed by the magnitude of the tasks required in the face of externally generated and accelerated development activity. They never seemed to "catch up" as their functions required more lead time and expertise than were available locally, even though external funding support was ostensibly provided for some elements of their resource management functions.

For example, the establishment of a Virgin Islands environmental management agency, the Department of Conservation and Cultural Affairs (DCCA) in 1968 tended to encourage a false sense of environmental security. It was simply too new and too complex an undertaking to be effective in its early years. The institutionalization of any new, broadly focused and "technically" based government department (or its ministerial equivalent) takes time, is fraught with organizational, funding and staffing problems and is destined for a difficult first decade of trial and error learning, with some successes and many failures. The Mangrove Lagoon was, unfortunately, one of the latter.

DCCA's agenda from 1970 onward was too full to allow the agency to pay much attention to the Mangrove Lagoon (although it did, with off-island funds, support several studies focused on the Lagoon but not properly aimed at the right issues). Therefore, when the new, externally funded Virgin Islands Coastal Zone Management Program was approved in 1978 by the local legislature (based on a three-year planning effort) and assigned to DCCA to administer, those within the agency and those outside concerned with coastal resources somewhat naively assumed that a balance could be struck between developmental pressure and environmental imperatives in coastal areas. Hope may spring eternal, but unfortunately reality creeps in, and in the case of the Mangrove Lagoon, the Virgin Islands' CZM program was fundamentally flawed. Using an external (federal U.S.) model, it split out a relatively narrow "coastal zone" along the land/sea interface into a two-tier demarcation, a) ignoring the fact that, in small islands, the <u>entire</u> island is a coastal zone and b) excluding from the CZM program's purview and permitting jurisdiction the entire inner core of the island and thus most upland "watershed" areas (for example, the most heavily populated segments of the Turpentine Run-Mangrove Lagoon drainage basin).

There was also a technical failure of researchers, planners, and managers to address the full spectrum of driving variables within the system. The numerous studies of the natural system and its changing characteristics produced mostly negative management recommendations of the "don't do this anymore" character, with little concern for how to effect needed changes in user behavior, management structures and policy. At no time was there a systematic investigation of the social system and its characteristics, limits, changes, and driving variables--which were continually interacting with the natural parameters of the Mangrove

Lagoon and its watershed.

Between 1960 and 1984, the Mangrove Lagoon watershed experienced the emergence of a variety of new social units of direct and indirect users of the Lagoon. In 1960 there were only farmers, fishermen and a sprinkling of residents and small commercial establishments (served by septic tanks). By 1984 there were nearly 500 vessel owners, an active marine industry, thousands of low-income public housing residents, thousands of middle-income single family dwellings, thousands of apartment dwellers and owners, and hundreds of commercial businesses. To some, this was progress. But there were numerous deferred or hidden costs, not the least of which was the degradation of the Mangrove Lagoon.

Finally, the Virgin Islands Mangrove Lagoon example illustrates several additional technical problems worthy of mention.

- There was a general failure to recognize the fact that the aggregate effect of degradation in an ecosystem like the Mangrove Lagoon can be worse than the sum. Initially, incremental changes are minimized and considered acceptable because the natural ecosytem is "working" and can handle the changes. But in later stages, larger incremental changes are justified as inconsequential (in the presence of the aggregate pollution effect). The argument is made that by concentrating polluting activities in one location, the use of other still pristine areas for those same activities will be avoided.
- There was a failure of government to abide by its own established rules and to apply the same environmental standards to itself as it requires of the private sector. Permit systems involving subjective judgments by the permitting agency only work well when everyone assumes the procedure is "fair" and "reasonable." When, for example, government agencies subvert this system by manipulating the process through subterfuge, or by applying higher "anti-pollution" or environmental quality standards to others than they are willing to

honor, then the permit system will break down--not in form but in function.

- There was a tendency on the part of all off-island, external development funding agencies involved in Lagoon watershed development to ignore the environmental impact of their lending or grant input. It is almost as if there were a separate set of less stringent rules for "offshore" areas, but, as O'Riordan (1981) and others have noted, it is unrealistic to assume that external (off-island) funding sources and institutions will voluntarily seek to establish the full spectrum of environmental costs or be willing to internalize them, within discrete project budgets. However, until such costs (representing a draw-down on the natural and social systems' capital stock) are identified and quantified, development planning and growth management will continue to generate unanticipated environmental crises, disbenefits and ecosystem losses, leaving islands at risk.
- The Virgin Islands' experience demonstrates that the impact of inappropriate capital-intensive technologies on fragile insular ecosystems will tend to reduce long-term resource flexibility because of the virtually irreversible alterations to specialized and highly complex land/sea ecosystems caused by such intrusions. This dysfunctionality results from the incompatibility of grafting high-volume technologies onto small closed environments with a very limited capacity to absorb the residuals (McElroy, 1978b). As McElroy has noted, "The result is the substitution of man-made inputs for irreplaceable natural ones, and in the long run development options are restricted and perverse feedbacks reduce the viability of environmentally sensitive industries like tourism. Such technological dependence chronically limits future local options" (McElroy, 1978b).