# Water Resources Development in Small Islands
## Perspectives and Needs*

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The paper reviews the special problems of small islands in the field of water resources development. The mode of occurrence of surface and groundwater resources in the smaller Caribbean Islands is described along with the problems which arise from unfavourable hydrological conditions.

A brief survey is given of the various types of water supply systems which have been developed to meet the requirements of the resident population and the tourist sector of the islands. Institutional deficiencies are discussed as they relate to the problems being experienced in the management of public water supply agencies and the conservation of water resources.

### 1. INTRODUCTION

The purpose of this paper is to review the status, problems and strategies of water resources development in the smaller islands of the Caribbean with particular reference to the 12 island-states listed in Table I. Two of these island-states are located in the north-western Caribbean region, the Cayman Islands being approximately 180 miles to the south of Cuba and the Turks and Caicos Islands approximately 90 miles to the north of Hispaniola. The other islands are located in the eastern Caribbean within the roughly semicircular chain of islands (known as the Lesser Antilles) which extend from Puerto Rico to the north-eastern coast of Venezuela.

In this context, the term 'small island' is used to define an island with an area of less than 500 square miles and a population of less than 500 000. Table I also shows the area and population statistics for the group of islands being considered in this paper.

TABLE I
Area and Population of Small Islands in the Caribbean

| *Country* | *Area (square miles)* | *Population* |
|---|---|---|
| Anguilla | 35 | 6500 |
| Antigua | 108 | 72 000 |
| British Virgin Islands | 59 | 9000 |
| Montserrat | 39 | 14 000 |
| St. Kitts and Nevis | 101 | 55 000 |
| Dominica | 290 | 80 000 |
| St. Lucia | 238 | 123 000 |
| St. Vincent | 150 | 107 000 |
| Grenada | 120 | 110 000 |
| Barbados | 166 | 250 000 |
| Cayman Islands | 100 | 15 000 |
| Turks and Caicos Islands | 193 | 7500 |

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## 2. PHYSIOGRAPHY

The physiography of the islands reveals two distinct types. Within the Eastern Caribbean group most are of volcanic origin with high mountains which radiate outwards from multiple volcanic centres. The other islands are mainly composed of limestone derived from reef-building corals. These islands tend to be elongated in shape and are of low relief—the highest point on many of them being less than 100 feet above sea level.

## 3. WATER RESOURCES

Rainfall in the islands follows a distinct seasonal pattern with a dry season during the first half of the year and a rainy season during the latter half. The volcanic islands enjoy relatively abundant rainfall although with pronounced spatial variations. Averages of around 100 inches per year are typical. In the limestone islands, rainfall is much lower and ranges from about 27 inches per year in the Turks and Caicos Islands to about 60 inches in Barbados.

Surface water resources occur as small streams draining catchment areas of limited areal extent. In the more mountainous islands, streams are steeply sloping and flow in narrow valleys.

Because of high rainfall in the catchment areas, most of the streams are perennial although with significant flow variations dictated by the seasonal pattern of rainfall. In the dry season, average stream-flows are generally less than 50% of wet season flows. Diminishing dry season flows have been reported from some catchment areas whre deforestation is taking place. In one catchment area in Dominica, for example, deforestation has been accompanied by a reduction in average dry weather flows from 1.9 million gallons per day (mgd) to 1.0 mgd. This problem is of special significance since suitable sites for impounding reservoirs are non-existent.

In the limestone islands where rainfall is lower and the subsoil more permeable, groundwater usually constitutes the main source of supply. It occurs as a two-density system with freshwater in the form of a thin lens floating on the heavier seawater. Since the two liquids are miscible, a sharp interface betwen the two is only a theoretical concept and, in actuality, there is a transition zone of brackish water. The thickness of the freshwater lens is a function of net recharge (replenishment minus pumpage), the permeability of the aquifer formation and distance from the shoreline. Two typical examples are given in Fig. 1 showing maximum lens thicknesses of about 50 feet in Grand Cayman and 60 feet in Barbados. The Barbados example demonstrates the effect of pumping—upconing and a widening of the transition zone in the area of the pumping well. In some of the smaller islands, net recharge and/or distances from the shoreline assume such small proportions that the freshwater lens is of negligible thickness and the transition zone of brackish water extends to the water table. This is the situation in Anguilla, parts of Antigua and some of the islands in the Grenadines and the Turks and Caicos.

## 4. WATER SUPPLY SYSTEMS

The conventional water supply system in the islands are of three basic types. Systems which utilize surface streams consist of a small intake across the stream, a raw water main to the treatment plant and a transmission and distribution network. Intakes are usually located in the upper reaches of the catchment where the quality of the raw water is good and the risk of pollution from human waste is minimal. In the smaller systems, water treatment is mostly by sedimentation and/or chlorination although in the rural areas some systems have no provision for treatment. For the large systems serving the urban areas, full treatment is provided consisting of coagulation, sedimentation, filtration and chlorination.

The main problem faced in operating these surface-water systems arises from the substantial variation in yeidl which occurs as a consequence of fluctuating stream-flows and the lack of storage at the source. In the dry season, maximum demand coincides with minimum supplies and water shortages are experienced.

Groundwater supply systems consist of a production well and a transmission and distribution network with chlorination usually practiced as a precautionary measure against possible pollution by human waste. In order to control saltwater intrusion, drawdown has to be restricted to an absolute minimum. The common approach to this probem is either to maintain very low pumping rates or to use large diameter wells which

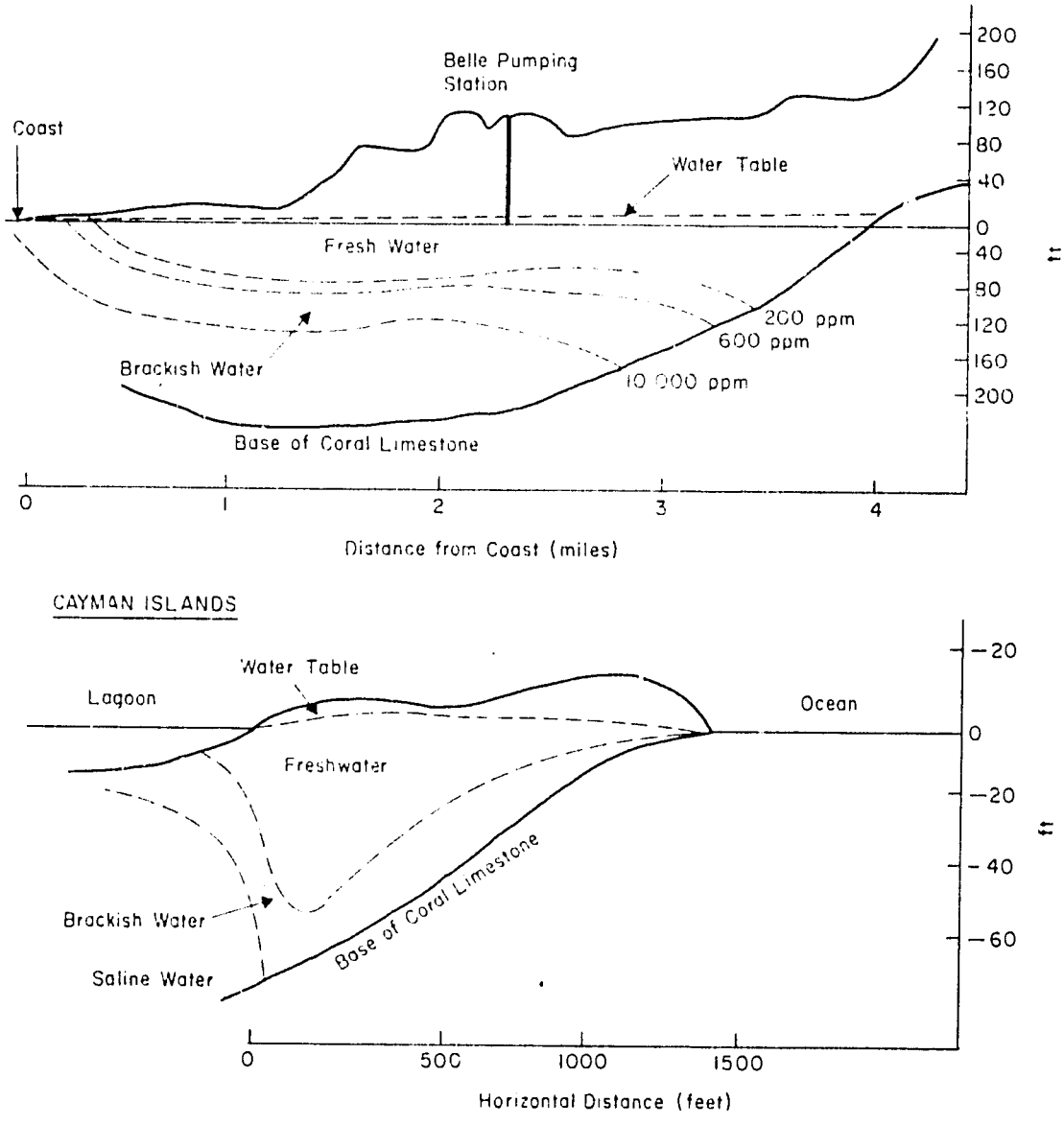


**Fig. 1.** Examples of groundwater in small islands.

effectively skim the surface of the lens without any significant drawdown. Before the introduction of modern well drilling equipment into the islands, the use of large diameter hand dug wells was common. Except in Barbados, however, this practice has now fallen into disuse and production wells are generally the standard mechanically-drilled small diameter type. These wells typically yield no more than 10 gallons per minute with the result that a large number is required to produce a reasonable supply of water. In Antigua, for example, a total supply of only 0.7 mgd is obtained from 50 wells. In Barbados, on the other hand, where large diameter wells with horizontal adits are used, a supply of 25 mgd is obtained from 14 wells, the most productive of which yields 8 mgd

with a drawdown of only 2 inches. A schematic drawing of a typical Barbados well is shown in Fig. 2.

The third type of system is the rainwater catchment which is used extensively in the smaller islands with no surface streams and only limited groundwater resources. The standard household system utilizes the roof to collect rainwater which is fed into a storage tank. In some islands, building regulations require the construction of a roof catchment system with a storage tank of a stipulated minimum size (usually 10–15 gallons per square foot of roof area). Purpose built rainwater catchments have also been constructed by public water supply agencies in a number of islands including the Grenadines and the Turks and Caicos. These normally consist of a concrete pavement from which runoff is conveyed into a storage tank for distribution to consumers. The main disadvantage of rainwater catchment schemes is the extensive catchment area and storage capacity required. A roof area of 3000 square feet and a storage capacity of 50 000 gallons are required to satisfy normal household needs. In the Caribbean Islands, roof areas usually range from 500 sqt are feet to 2000 square feet and most households are unable to afford storage tanks of more than 1200 gallons. Roof catchment systems therefore show considerable shortcomings.

With limited freshwater supplies, a few islands have already been forced to resort to non-conventional sources of supply. In the state of St. Vincent and the Grenadines, the barging of water between the main island (St. Vincent) and the Grenadines is carried out during the dry season when supplies from roof catchment systems became inadequate to satisfy even minimum domestic requirements. In Antigua, a multi-stage flash desalination plant was installed some years ago but was later abandoned because of technical problems and high operating costs. In the Cayman

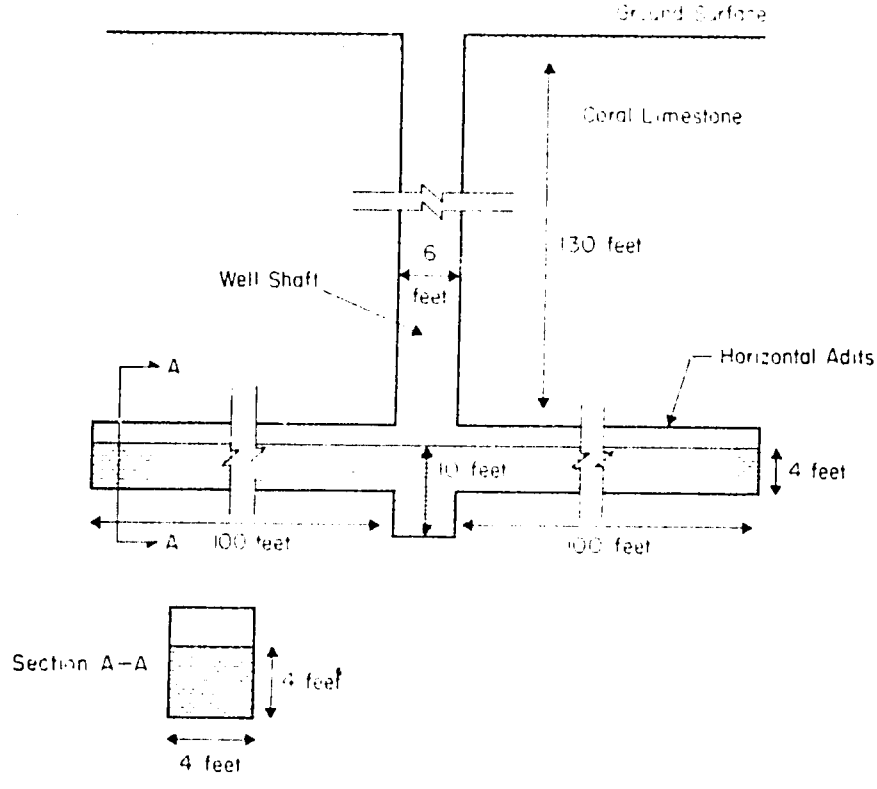


**Fig. 2.** Typical large diameter well—Barbados.

Islands, a vapour compression desalination plant provides a high priced (about US $20.00 per 1000 gallons) supply to the main tourist development area. The islands of Anguilla is now in the process of installing a small reverse osmosis plant which is expected to produce 20 000 gallons per day at a cost of US $22.00 per 1000 gallons.

The construction of water supply systems to provide water for irrigation has been carried out to only a limited extent. In Barbados some of the wealthier farmers whose land overlies the groundwater aquifer excavate their own wells and install supply systems to irrigate vegetable crops during the dry season. In Antigua, a number of mini-dams have been constructed across natural water courses to impound storm runoff for use by farmers. In general, the pattern of agriculture production in the islands is highly seasonal in nature with production being confined mainly to the wet season when rainfall is sufficient to satisfy the moisture requirements of crops.

## 5. WATER CONSUMPTION PATTERNS

The domestic and tourism sectors account for virtually all of the water which is consumed in the islands. The industrial sector is still limited and is confined mainly to light manufacturers which use water only for sanitary purposes.

In the domestic category, the main factors which determine the level of consumption are the method of supply (whether by household connection or by public standpipe) and the method of charging for water. Consumers who use public standpipes generally consume about 10–15 gallons per capita per day (gpcd). For consumers with house connections, the available data indicates a wide disparity between consumption by metered consumers and those who pay a charge which is independent of the amount of water used. Table II shows consumption data for three islands with the lowest being recorded by St. Lucia which has a system of universal metering. Consumption in the other two islands—where only a small proportion of domestic consumers are metered—is more than twice the recorded level in St. Lucia.

TABLE II
Water consumption in Selected Island Countries

| *Country* | *Domestic consumption (gpcd)* | *Hotel consumption (gpbd)* |
|---|---|---|
| Barbados | 92 | 133 |
| Dominica | 72 | 80 |
| St. Lucia | 36 | 122 |

In the tourist sector, water consumption is mainly dependent on the standard of tourist accommodation facilities. Table II shows that in Barbados and St. Lucia (which both have highly developed tourist industries), consumption ranges from 122 to 133 gallons per bed, per day (gpbd). In Dominica, on the other hand, where hotel standards are much lower, consumption is 80 gpbd.

## 6. THE INSTITUTIONAL SETTING

Water resources development in the islands is severely constrained by weak and ineffective institutions. In most of the islands, statutory corporations have been set up within the last 15 years to manage the public water supply systems. In the other islands, this function is carried out by a department of one of the Government Ministries.

Existing institutions suffer from a series of closely interrelated problems. They face constant financial difficulties because of inadequate tariffs and inefficient billing and collection systems. The basic principle that water supply charges should cover costs has not yet been accepted in the Caribbean Islands. Water utilities therefore face considerable political and consumer resistance whenever attempts are made to restructure tariffs in line with their requirements for financial viability. With limited financial resources, only the more pressing and immediate needs can be addressed and important functions such as waste control, preventative maintenance of mechanical plant and hydrological investigations are neglected. Most utilities report system losses of between 40 and 50% of production, but only two of them are known to have allocated resources to a systematic programme of waste control. The breakdown of mechanical plant caused by a lack of preventative maintenance is a common feature of utility operations. In the design of new systems, the absence of basic hydrological data results in crude and inaccurate estimates of yield and, frequently, the overpumping of aquifers. In one island, a

treatment plant which was designed with a capacity of 3 mgd has never been operated at more than 30% of the capacity because of a gross over-estimation of the yield of the supply source. The over-pumping and associated saltwater contamination of aquifers has occurred in several islands.

With considerable financial and technical difficulties, water utility management in a small island environment is inevitably a frustrating experience, compounded by political interference and inadequate remuneration levels. A shortage of trained staff is therefore common, especially in critical areas such as financial and technical management.

Institutional deficiencies now represent a major obstacle to the financing of capital expansion and system improvement works which are so urgently required in many of the small Caribbean islands. Development banks and other aid agencies are understandably reluctant to provide financial assistance to institutions which are poorly managed and which are unable to generate adequate revenues to cover even essential operation and maintenance costs. Most of the utilities now find themselves in a vicious circle. As the quality of service deteriorates, public resistance to tariff increases become more vociferous and reinforces the already strong political resistance to these increases. In order to obtain financial assistance to expand and improve the quality of service, however, increased tariffs are required to ensure financial viability.

An ineffective approach to the conservation of water resources is common throughout the islands and is closely related to existing institutional deficiencies. This problem is further aggravated by the absence of clearly defined objectives in the area of water resources management and comprehensive legal codes for the control of land and water resources. With a general shortage of trained staff and limited finances, the functions which are crucial to the conservation of water resources are completely neglected. Freshwater lenses are therefore developed without a complementary monitoring programme to ensure that pumping wells do not become affected by saltwater contamination. There are no effective catchment controls and as a result, several catchment areas have become subject to flash floods, high sediment loads in streams, and a serious reduction in dry weather flows caused by indiscriminate deforestation. The effects of agricultural land use on water quality have not yet been systematically evaluated.

## 6. CONCLUSIONS

This paper has attempted to review the status, problems and strategies of water resources development in the smaller islands of the Caribbean. Because of small size water resources in these islands are severely limited in quantity and occur under unfavourable hydrological and topographical conditions. In some islands, surface streams are non-existent and groundwater is of poor quality. A heavy reliance is therefore placed on roof catchments and desalination.

Although some progress has been made in the islands in the development of water resources, a new and more efficient approach is now needed, especially in the management of water supply agencies and the conservation of water resources.

The need for a more efficient approach is demonstrated by the deteriorating situation in the water supply sector which manifests itself in poor planning and system operation procedures, a diminishing resource base and severe difficulties in obtaining financial assistance for capital expansion and system improvement works.

The immediate requirement is for well managed and financially viable institutions operating within a rational legal framework.

In the islands with serious supply deficiencies, there is some scope for the use of rainwater catchment schemes utilizing low cost materials both for the catchment and the storage facility. In this regard, there is a need for the dissemination of information on available materials which can minimize the cost of such schemes.