To the Graduate Council:

I am submitting herewith a thesis written by Sheila Salwa Carman entitled "The Effectiveness of a Small, Participatory Water Development Project in the St. Vincent Grenadines, West Indies." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

Dr. Carol P. Harden, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

THE EFFECTIVENESS OF A SMALL, PARTICIPATORY WATER DEVELOPMENT PROJECT IN THE ST. VINCENT GRENADINES, WEST INDIES

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Sheila Salwa Carman
August 1996

ACKNOWLEDGMENTS

I wish to thank the many individuals who have assisted me in the course of my thesis research and preparation. First, I am indebted to the Geography Department for the financial support needed to complete my course of study. Additional recognition goes to Dr. Carol Harden for her guidance, patience and encouragement through my research and for critical readings of earlier drafts of this document. Thanks go to Drs. Lydia Pulsipher and John Rehder for serving on my committee, with special gratitude to Dr. Pulsipher for introducing me to Caribbean culture and supporting and encouraging me to conduct research there and to Dr. Rehder for sharing his photographic expertise. I would like to express my gratitude Will Fontanez and the good-natured people in the cartography laboratory for their cartographic assistance.

I am grateful to S. Conrad Mason, Regional Programme Co-ordinator at the Caribbean Conference of Churches for drawing my attention to the project and supporting my research efforts. I am appreciative of all the help I received in St. Vincent and the Grenadines with logistics and the sharing of information from Carleton Williams of the SVGCC, Fathers Andrew Roache and Mark DeSilva of the Cathedral of the Assumption in Kingstown, Dormott Olliviere, Ella Roache and Father Adams, former committee members in the Grenadines and Honorable Stephanie Browne, GSVG Representative for the southern Grenadines. I owe special gratitude to Tom and Theo Saunders, Bertina Sandy, Stephanie and Ben Wilson, Justin Olliviere and Marilyn Roache. All of whom made me feel welcome in their homes through their generous hospitality.

I am particularly appreciative of the friendly helpfulness of the people that I met in the St. Vincent Grenadines. Special thanks to the captain of the "Snapper" for safeguarding my untended luggage until I returned to his ship, to Jeannette Wall for sharing her rainfall data records, and to the many people who willingly shared information regarding their surroundings, rain water harvesting and their water tanks.

I would like to acknowledge the financial support I received from the W. K. McClure Foundation for the Study of World Affairs and the Stewart K. McCroskey Memorial Fund. This support enabled me to travel to the Caribbean (1994) where I originally contacted the CCC and to the St. Vincent and the Grenadines (1995) where I conducted my research.

Last, but not least, I am appreciative for the encouragement and support of my family and friends whose support and love have helped make this endeavor possible. I am particularly indebted to daughters Sandy in Boston and Trish in Denver and to son, Jim in Memphis who inspired me to continue on with my education and, to my friends, Carol Knapp and Vicki Berry, for who let me stay in their apartments during my transitions. I thank Catherine Broyles, Herb Iburg and Dr. Robert Champlin for their certitude. Special acknowledgment is due to members of my Thursday night support group who bolstered my courage and confidence to continue on this journey.

ABSTRACT

A group of about 60 arid islands in the East Caribbean make up the St. Vincent Grenadines. The absence of perennial surface water and fresh ground water has led residents of the St. Vincent Grenadines to depend on the collection and storage of rain (rain water harvesting) as the sole source of potable water.

My study is a follow-up evaluation of the effectiveness of a small, low-cost, self-help development project, administered by the Caribbean Conference of Churches and the St. Vincent and the Grenadines Christian Council, that assisted 50 needy households in building ferrocement water tanks at their homes in Bequia, Canouan, Mayreau and Union in 1985.

Overall, the ferrocement water tank project was effective in attaining its original goals. The water supply situation for most of the households that received tanks under this project has improved. Problems with the quality of completed tanks, sporadic inconsistent maintenance and misunderstandings regarding the criteria used to select tank recipients and of the project scope emphasize the need for close monitoring during and following project implementation, and the importance of comprehensive community participation and training.

I evaluated the present condition and operability of the original ferrocement tanks and found several with problems attributable to improper construction techniques. Tank mortar made with water or sand containing sodium chloride, insufficient cement in the mix or shoddy workmanship may be responsible for the poor quality and condition of several tanks. However, with proper attention to construction details, ferrocement tanks provide an economical method of supplying household water storage for dry Caribbean islands and the ferrocement technology is readily adaptable to self-help projects.

The extent to which people replicated the ferrocement tanks was quantified. The design has been replicated in the St. Vincent Grenadines, albeit not to the extend hoped for by the administrating organizations. Nonetheless, this may be taken as evidence of the acceptance and transferability of the technology.

To evaluate the storage capacity needed to supply sufficient household water supply, a tank water balance proved to be a useful tool. Results of my evaluation of system size relative to existing rainfall data and household water use reiterates the need to size rain water tanks, within financial constraints, to those two conditions. A critical lesson learned from the use of the tank water balance is the need to provide gutters on all possible roof slopes in order to maximize water yield.

TABLE OF CONTENTS

CHAPTER		PAGE
I	INTRODUCTION	1
	Problem	1
	Purpose and Significance of This Research	4
	Thesis Organization	5
II	THE ISLANDS AND THEIR FRESH WATER SUPPLY OPTIONS	6
	Physical and Human Landscape of the Study Area	6
	Options for Water Acquisition in the St. Vincent Grenadines	13
III	THE FERROCEMENT WATER TANK PROJECT	19
	The CCC Project Development	19
	Project Implementation	21
	Roof Catchment Systems: An Overview	22
	Rainwater Cisterns Constructed Using Ferrocement	25
IV	RESEARCH METHODS	30
V	RESULTS	36
	Rainfall	36
	System Condition and Function	41
	Sizing	44
	Project Goals	51
	Project Structure and Administrative Process	53
VI	DISCUSSION	56
	Rainfall Patterns	56
	System Condition and Function	56
	Sizing	56
	Economic Appropriateness	61
	Housing Issues	61
	Project Goals	62
	Project Structure and Administrative Process	64
VII	CONCLUSION	68
BIBLIOGRAPHY		71
APPENDICES		79
	APPENDIX A CCC Project Proposal	80
	APPENDIX B Rainfall Tables	87
	APPENDIX C Tank Water Balance Spread Sheets	94
	APPENDIX D Survey Results	99
VITA		103

LIST OF FIGURES

FIGURE		PAGE
Figure 1.	Study area with St. Vincent and Grenada shown	7
Figure 2.	Bequia, St. Vincent and The Grenadines	10
Figure 3.	Canouan, St. Vincent and The Grenadines	11
Figure 4.	Mayreau, St. Vincent and The Grenadines	12
Figure 5.	Union, St. Vincent and The Grenadines	14
Figure 6.	SVGCC/CCC ferrocement water tank	26
Figure 7.	SVGCC/CCC water tank under construction	28
Figure 8.	Painted ferrocement water tank in Bridgetown, Barbados	29
Figure 9.	Graph depicting monthly rainfall statistical data derived from GSVG, CWSA data for Bequia.	37
Figure 10.	Graph depicting monthly rainfall statistical data derived from GSVG, CWSA data for Union.	38
Figure 11.	Graph depicting monthly rainfall statistical data derived from Wall data for Union	39
Figure 12.	Ferrocement tank with exposed reinforcing wire along top seam.	42
Figure 13.	Makeshift hatch cover; a piece of corrugated metal laid over hatch opening	42
Figure 14.	Graph from tank water balance using median rainfall data for Union and 25 square meter cra depicting water level at month's star	47
Figure 15.	Graph from tank water balance using median rainfall data for Union and 45 square meter cra depicting water level at month's start	47
Figure 16.	Graph from tank water balance using minimum rainfall data for Union and 25 square meter cra depicting water level at month's	48
Figure 17.	Graph from tank water balance using minimum rainfall data for Union and 45 square meter cra depicting water level at month's	48
Figure 18.	The effect of rationing on tank water supply	49

LIST OF TABLES

TABLE **PAGE**

Table 1 Summary of field survey re: tank water supply sufficiency with measured roof areas..... 45

Table 2 Summary of roof area required to provide 10 liters of water per day per person for each household size indicated during severe drought..... 46

Table 3 Monthly incidence of tank water supply deficit, overflowing and non-rationing derived from tank water balance computation..... 49

LIST OF ABBREVIATIONS

CCA ---------- Caribbean Conservation Association
CCC ---------- Caribbean Conference of Churches
CIDA ---------- Canadian International Development Agency
cra ---------- contributing roof area
CWSA ---------- Central Water and Sewer Authority
DSEA ---------- Department of Social and Economic Affairs
DTCD---------- Department of Technical Cooperation for Development
DTCD---------- Department of Technical Cooperation for Development
EC$ ---------- Eastern Caribbean Dollar
GSVG ..... Government of St. Vincent & the Grenadines
SVGCC ---------- St. Vincent & the Grenadines Christian Council
UN ---------- United Nations
US$ ---------- United States Dollars
WHO---------- World Health Organization

CHAPTER I
INTRODUCTION

Problem

Access to ample, safe drinking water is of growing concern around the globe (Speth, 1994). Water is fundamental to human life: humans require fresh, potable water for drinking and food preparation, and where it is abundant, it is used for other purposes such as laundry, cleaning, personal hygiene and toilet flushing. Worldwide, water consumption varies greatly. For instance, domestic use of fresh water in the United States may be as much as 454 liters per person per day (Nebel & Wright, 1993), whereas domestic use in the West Indies is typically less: 350 liters per person per day in Barbados (which is relatively well developed), 270 liters per person per day in Dominica (Falkland & Brunel, 1993) and 136 to 227 liters per person per day on St. Vincent (CCA, 1991). In the St. Vincent Grenadines, where government catchments supply only slightly more than two liters per person per day in times of drought, the availability of water limits its use (UN, DTCD, 1990).

Prolonged periods of drought and the absence of perennial surface water and fresh ground water in the Grenadines lead to severe water shortages during the dry months. This lack of adequate potable water is seen as such a major problem that both public and private institutions have addressed it. Religious institutions in the St. Vincent Grenadines have also played an important role; the St. Vincent and the Grenadines Christian Council (SVGCC) and the Caribbean Conference of Churches (CCC) have worked cooperatively to provide potable water as part of their attempt to improve access to basic human needs (CCC, no date).

Filling the need for water has led to a variety of strategies for acquiring, storing and distributing water in the St. Vincent Grenadines. A limited number of private homes have brackish wells to provide water for toilet flushing, showers and laundry (Browne, 1995) and the islands of Union and Bequia (pronounced: Beck $\bar{\text{w}}$ee) have brackish wells for community use. Rain water, collected from house roofs and paved hillsides, is stored in tanks, cisterns, drums and other containers for potable uses. Unfortunately, not everyone in the St. Vincent Grenadines is able to afford the luxury of a private cistern, but each island has at least one public cistern. During dry spells, water supplies stored in community tanks are often not sufficient to meet islanders' needs and water from reservoirs on St. Vincent is transported on government boats to the Grenadines by the Central Water and Sewer Authority (CCC, no date; Browne, 1995). Water from public catchments in the St. Vincent Grenadines is rationed; for example, Unionites who do not have a cistern at their home are allowed to collect one 20-liter bucket per person on the one day per week that is designated for the neighborhood in which they reside. Additionally, spigots that deliver water from public cisterns in Mayreau and Canouan were shut off at the start of the rainy season in July 1995. Many major resorts in the Grenadines maintain their own potable water supply by using rain water catchments or by

importing water. Additionally, desalination plants are used by hotels on Canouan (pronounced: can ōu wan) and Union (Johnson, 1995).

Increases in population and in tourism are intensifying the demand for water throughout the Caribbean where greater numbers of users are consuming more liters per capita than in the past. For example, tourist use of potable water in Bermuda is now estimated to be 409 liters per person per day (Waller, 1982). Even in times of scarcity, tourists rarely experience the effects of water shortages that are felt by locals and are not discouraged from visiting. According to the *Boston Globe* ("There is Water," 1995), in Puerto Rico water was being managed during a drought to insure that tourists would not be affected by severe water shortages. Although water to homes and businesses was turned off periodically, it would not be turned off in hotels or tourist restaurants. In the St. Vincent Grenadines, water usage by residents is extremely low while water usage by resort hotels and similar tourism-related establishments remains consistent with that of other Caribbean areas [Caribbean Conservation Association (CCA), 1991]. Promoting tourism in the Grenadines will put additional pressure on limited water supply.

Census data are not available for the Grenadines alone, but government census estimates indicate that the population of the whole country of St. Vincent and the Grenadines appears to have entered a period of rapid growth following 1970 (CCA, 1991). My experience and anecdotal evidence I acquired in 1995 confirm that the populations of certain Grenadine islands are increasing rapidly. The Honorable Stephanie Browne, Government of St. Vincent and the Grenadines (GSVG) Representative for the Southern Grenadines, informed me that Union's population in 1995 was about 2,800, a 47% increase over the 1989 census estimate of 1,900. While the GSVG previously may have underestimated population, some increase also may be due to emigration from St. Vincent. This was brought to my attention by a recently retired employee of a social service section of the Ministry of Health on Union Island. She expressed her concern about the stress being put on the limited water supply by the increased numbers of Vincentians moving to Union (Ackie D., 1995). Another indication of population increase comes from the sign I read in July 1995 while walking on Mayreau (pronounced: my rōw), which announced its population to be 223, 31% more than the 1989 census estimate of 170 (CCA, 1991).

On all these islands, household water consumption varies depending on the number of people in the home, the season, size and ownership of cistern and proximity to a public well or catchment; and a variety of methods are practiced to keep water use to a minimum. In some instances, water collected from outbuilding roofs in open 250 liter (55 gallon) drums is used to wash dishes, while cleaner water, stored in closed cisterns, is used for rinsing. The gray water is then saved for potted plants. Laundry is done outside by hand, in plastic pails on what seems to be a weekly schedule. Indoor plumbing is not common on the Grenadines and is almost absent on Mayreau. Some people have showers piped to improvised stalls adjacent to their water tanks. Others bathe using buckets of water from their cisterns or from public or

private, brackish wells. People also bathe in the sea, rinsing their faces and hair with fresh or brackish water when they reach home or the public well (Hall, 1995).

A few examples from my field observations illustrate the extent to which water conservation looms large in daily life. I observed a frenzied homeowner climbing a ladder during a heavy rain to unclog an overflowing gutter so that the water would flow into one of his water tanks. Later, he was disturbed when his 1,500 liter (330 gallon) plastic water tank overflowed as a result of the same storm. He quickly set up a pump to transport the water to his large, concrete cistern, remarking that he did not want to lose any water. One woman, whom I met, had an array of six 250 liter (55 gallon) drums to collect the overflow from her water tank. Most people willingly share their excess water with their neighbors in times of need but, because of water scarcity, thievery is sometimes a problem. I was told by Father Mark DeSilva, parish priest for the southern Grenadines, that a layman, chosen for his large size and strength, is responsible for rationing church cistern water to the Mayreau community when the public supply has been depleted. An elderly woman related a story to me about a time when she arrived home to find her neighbors helping themselves to water from her tank. Another had a locking box constructed around the spigot of her tank to discourage would be "water thieves."

Providing a sufficient supply of water for all has been and continues to be a goal for local leaders, governmental officials and, regional and international groups. This need was of such importance that the United Nations declared 1981-1990 as the International Drinking Water Supply and Sanitation Decade. The ultimate goal of the Decade was to provide access to potable drinking water and sanitation services to all people worldwide (Whyte, 1986; UN, DTCD, 1989a) and community participation was a key strategy in the design of new projects launched during the Decade (to meet its goal) (Chauhan, 1983; Whyte, 1986). The United Nations has continued to promote self-help and the use of appropriate technologies in implementing water projects (Speth, 1994).

Jointly, the Caribbean Conference of Churches (CCC) and the St. Vincent and the Grenadines Christian Council (SVGCC) administered a self-help project in 1984-85, referred to in this thesis as the SVGCC/CCC Project. Funded by the Canadian International Development Agency (CIDA), this project resulted from and was implemented during the International Drinking Water Supply and Sanitation Decade (Mason, 1994). The project provided financial and technical assistance to 50 needy households in the St. Vincent Grenadines, enabling them to install household ferrocement tanks (CCC, no date). Ferrocement is a technique for reinforcing cement by plastering it in layers over heavy gauge steel wire and wire mesh (Pacey, 1986). Chapter III of this thesis contains a detailed description of this project.

The SVGCC/CCC Project was completed in 1985 but, like many development projects, its effectiveness had not been evaluated after the fact. Lack of follow-up left several questions unanswered regarding the overall success of the project, especially questions about the water quantity, the ongoing condition of the tanks and the householders' satisfaction with the cistern water (Mason, 1994). This study

assesses the success of the SVGCC/CCC Project in terms of the operating efficiency and durability of the equipment installed and the satisfaction of participants over the past 10 years.

Purpose and Significance of This Research

The purpose of this study was to evaluate the effectiveness of the Caribbean Conference of Churches' (CCC) and the St. Vincent and the Grenadines Christian Council's (SVGCC) household ferrocement water tank project as a sustainable means of providing potable water to citizens of the St. Vincent Grenadines. My evaluation focuses on the SVGCC/CCC Project as it was implemented on four islands: Bequia, Canouan, Mayreau and Union.

Several things influenced my interest in doing this evaluation. First, was a desire to learn how Grenadineans manage a very limited water supply. I have learned, through necessity to find ways to appreciate the value of and conserve potable water. I have spent many an hour repairing a broken down well pump and digging-up and replacing the well point in the front yard, and many a day without the luxury of running water. During those days I melted snow for non-potable uses and fetched water in buckets from neighbors' taps. Furthermore, my experiences while a student at the University of Tennessee introduced me to alternative methods of water acquisition, small development projects, and the history, amiable people and the unique problems and attributes of small island countries of the Caribbean. Finally, added to my interests in the project was the encouragement I received from S. Conrad Mason, Regional Programme Co-ordinator at the CCC.

The objectives of this study are:

- To evaluate the water storage needs for private cisterns in light of present rainfall patterns in the Grenadines;
- To determine the appropriateness of the ferrocement technology in terms of durability, cost and sizing;
- To evaluate the effectiveness of the project in terms of whether the goals of the SVGCC/CCC were met; and
- To evaluate the project's effectiveness in terms of its structure and administrative process.

To gauge the appropriateness of the chosen tank size, I evaluated system size relative to existing rainfall data and household water use. I visited the St. Vincent Grenadines during the summer of 1995 and evaluated the condition and operability of the original ferrocement tanks so that I could use them as an indicator of the soundness of the ferrocement technology. The extent of replication of these tanks by others is taken as evidence of the acceptance and transferability of the technology. I was also interested in determining the recipients' assessments of water quality, quantity and system maintenance and any health problems that have been attributed to the water in the new ferrocement tanks.

Monitoring a development project during and following its implementation can ensure that the project continues to meet the needs it was designed to meet and reveal lessons learned. The need for such

monitoring has been the subject of concern to the United Nations, aid agencies, non-governmental organizations and individuals interested in development projects (Riney, 1972; Ativon, 1988; Dunska, 1988; Surwavuba, 1988). The UN Department of Technical Co-operation for Development (1988) supports follow-up evaluations as a mechanism to make future water project planning much more effective.

Contemporary development theory encourages community participation in small scale, self-help projects providing easy to manage and maintain systems that ensure access to basic necessities (McAfee, 1991; "Community Participation...," 1993; Speth, 1994). Community involvement in all aspects of planning, building, financing and maintaining water projects has been integral to the success of other water projects (Jenkins-McLean, 1991; "Community Participation...," 1993; Wright, 1994; Rodda, 1995). The SVGCC/CCC Project in the Grenadines appears to have been grounded in certain components of this development approach and is an early example of community-based, low cost, sustainable development that incorporated a technology expected to be appropriate for these islands. Thus, results of this evaluation can be used to improve future development projects.

Thesis Organization

The first section in the next chapter provides the reader with an overview of the physical and cultural settings of the Grenadines, about which little has been written as most literature focuses on the main island of St. Vincent. The next section describes options for acquiring water in seasonally dry islands, giving the advantages and disadvantages for each, and developing the rational that rain water harvesting is the most suitable means for acquiring fresh water in the Grenadines.

Chapter III provides a brief background of the Caribbean Conference of Churches (CCC) and the St. Vincent and the Grenadines Christian Council (SVGCC), followed by descriptions of the SVGCC/CCC Project design and the implementation of the project. In the remainder of Chapter III, I detail the process of collecting rain water from house roofs and explain how ferrocement tanks are constructed. This background information gives relevant details and establishes a context within which to analyze the current condition of the ferrocement water tanks and the overall effectiveness of the project.

In Chapter IV, I describe the methods used to collect and analyze data. In Chapter V, I present the information gathered in my research, including a description of the physical condition of the SVGCC/CCC tanks and information on roof size, household size and the sufficiency of water supplied by the tanks. I also present interview responses from tank owners, contractors and former oversight committee members regarding the project administration, tank construction and condition, and I estimate water use based on my observations in the field.

In Chapter VI, I discuss and analyze results of my investigation and re-examine these findings in light of project goals. The concluding chapter summarizes the outcome of this evaluation and offers recommendations for future projects.

CHAPTER II

THE ISLANDS AND THEIR FRESH WATER SUPPLY OPTIONS

Physical and Human Landscapes of the Study Area

The St. Vincent Grenadines are a chain of approximately 60 small, arid islands and cays (coastal reefs or sandy islands) of volcanic origin running south from St. Vincent to the island of Carriacou, Grenada, in the eastern Caribbean (Figure 1). They range in area from large rocks to about 18 square kilometers. None have elevations high enough to induce orographic precipitation, hence they must rely on whatever precipitation is produced by the interaction of large air masses.

The climate of the eastern Caribbean is tropical with seasonally wet and dry periods. Monthly temperatures for Kingstown, St. Vincent, reported between 1983 and 1987, ranged from of 32.8 degrees Celsius (91°F) to 19.4 degrees Celsius (66.9°F), while humidity ranged between 72% and 83% (CCA, 1991). No similar records are available for the Grenadines. Rainfall totals are lower and vegetation is much sparser in the Grenadines than in St. Vincent; therefore temperatures are likely to be higher. During my stay in the Grenadines, between July 10 and August 3, 1995, daytime temperatures generally rose to the low 30 degree Celsius range.

The fact that rainfall in the Grenadines is highly seasonal, erratic in occurrence and unreliable in amount exacerbates the effect of high evaporation. According to government records, annual rainfall may exceed 1,900 mm [GSVG, Central Water & Sewer Authority (CWSA, no date)], but independent records, shared with me by a resident, indicate that over several. consecutive years in the past, annual rainfall was below 1,000 mm in Union (Wall, no date; see also Appendix B). Historically the dry season is from January to May and the rainy season from June to December (CCA, 1991). Personal observations, local opinions and recent rainfall data suggest that the dry season may have lengthened over the past several years. Furthermore, the estimated mean annual potential evaporation of 1,000 to 1,500 mm/yr (CCA, 1991) often exceeds actual annual rainfall. Price (1988) lists insufficient rainfall as one contributing factor to the low plantation production in Bequia in the past.

The four Grenadines in this study are all rugged islands with steep slopes, sparse vegetation and no perennial, fresh surface water. The absence of fresh ground water and the ephemeral nature of surface water in the Grenadines may be due to several factors relating to their small size, hilly topography, impermeable soil and lack of adequate vegetation cover. Ponds and streams occur following rain events and/or throughout the wet season. I saw a pond in Canouan that was indicated as such on the government map, yet when I arrived in July it was a dry, sparsely vegetated depression. It filled with water shortly after my arrival following a day-long easterly wave storm.

One reason the present environment is sparsely vegetated is that trees have been harvested from the islands, first, before the eighteenth century, by Caribs who used the timber for canoe building, and later by

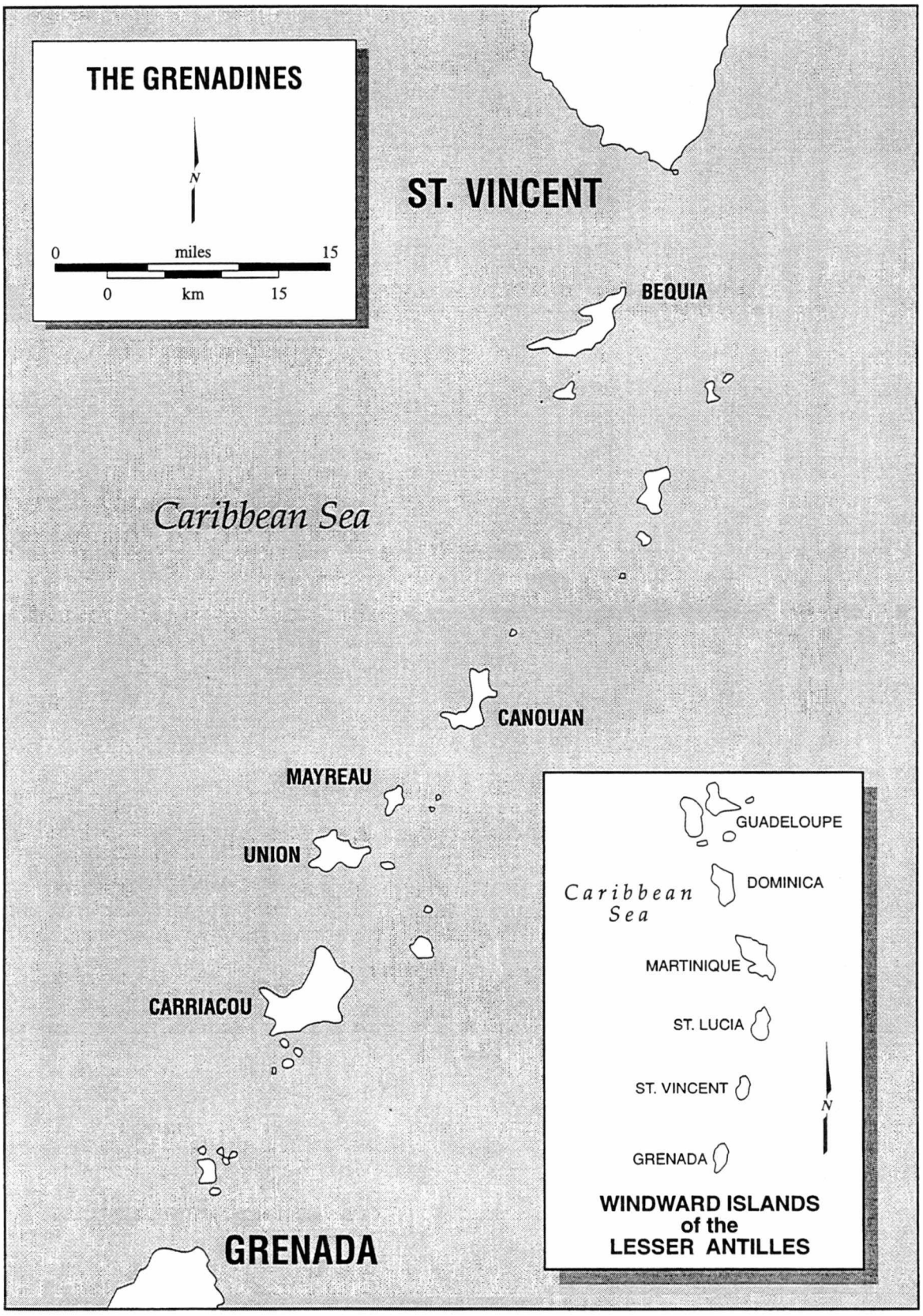


Figure 1: Study area with St. Vincent and Grenada shown.

European colonists who cleared large tracts of land to plant sugar cane and cotton (Price, 1988). Today, clearing for small plot cultivation and the overgrazing of untethered animals during the "let-go" (dry) season continue to diminish the remaining vegetation, which now consists of cactus, dry scrub and brush. Deforestation in the Grenadines appears to have increased the runoff of water and caused considerable erosion. I observed widespread runoff of silty water during the several, short intense rainfall events during my stay and saw many gullies that were formed by the runoff.

The Grenadines are occupied primarily by the descendants of Africans slaves brought to the region during colonization (Stephens, 1991). In 1776, four sugar cane plantations were being worked by African slaves in Bequia. That number increased to nine in 1828 when the island recorded its highest annual production (Price, 1988). Even tiny Mayreau had six cotton plantations and 66 slaves (DeSilva, no date).

Most residents currently live at or just above subsistence level (CCC, no date). In 1981, the percentages of men and women in Bequia receiving wages from employment were only 42.18 and 30.63 respectively (Price, 1988), while unemployment rates in the entire country of St. Vincent and the Grenadines were up to 23.5% in 1980 (CCA, 1991). My observations lead me to believe that the low employment rate in Bequia is characteristic of other islands in my study. Most men in the Grenadines earn a living through occupations connected with the sea, such as boat building, fishing and crewing on a wide range of ships, while women are primarily employed in full and part-time service positions in the tourist sector. Many women I observed or met earned money as vendors; some brought goods from St. Vincent to sell in the Grenadines. One woman roasted peanuts at her home in Canouan to be sold in St. Vincent. Other people provide for themselves through small plot cultivation and in other miscellaneous occupations (Price, 1988). Whaling, widespread in the area until the early twentieth century (CCA, 1991), is conducted on a very small scale by one crew from Bequia.

People live in adequate, small homes and spend most of their waking hours out-of-doors. Few have the financial means to own or maintain an automobile, but ownership of small boats is more common. Islanders transport themselves and their goods overland on foot, or on public transportation provided by taxi cabs and privately owned mini-van buses.

Cultivation of small, unirrigated plots is common in the Grenadines (Htoon, 1995). Peas, maize and cassava are grown for household use; while tomatoes, ground nuts and peppers are grown as cash crops (Price, 1988). Planting begins only after the rains start with the hope that the wet season will be sufficiently long to produce a harvest. During the summer months, when fresh produce is not available, it, and other goods, the mail and most people traveling from St. Vincent or between the islands must be transported from St. Vincent and elsewhere on the ferry, the "Snapper," which makes daily trips to Bequia but only goes to Union, Canouan and Mayreau three times a week.

Bequia, the largest and northernmost Grenadine, is 18 square kilometers (7 square miles) in area and its highest point is only 268 meters (879 feet) (GSVG, 1983a), too low to produce orographic precipitation

(Figure 2). Like its island neighbors, vegetation is sparse on Bequia but the remnant of a cedar forest persists in the interior (Price, 1988). The population of Bequia, Carib for "Island of Cloud" (GSVG Tourist Bureau, no date), is concentrated around Port Elizabeth, with its several commercial and tourist related businesses, and in the southern half of the island.

Potable water is supplied to the community by a large public catchment in Port Elizabeth while numerous private wells and one communal well deliver brackish water (Hadwen, 1987a). A second public water catchment with a 454,600 liter capacity is currently under construction uphill from the older, larger catchment (Htoon, 1995). Meanwhile, those living in areas away from Port Elizabeth must travel there or rely on roof collection systems for potable water. The hand pump at the public well in the community of Paget Farm, used by many to provide for non-potable water uses, is unreliable because it is broken more often than not due to overuse (Belmar, 1995). Hotels pump brackish well water for toilets/showers and collect rain water for potable uses (Hadwen, 1987a). Bequia has a reputation for fine boat building, and several yachts and sailboats were in the harbor, even in the off-season. A small airport has recently been constructed along the southwest finger of the island, adjacent to Paget Farm. Bequia has island-wide electric power.

The name Canouan also has Carib roots. It comes from the word Canouanne meaning Turtle Island (Stephens, 1991). Mount Royal, in the northeast, is the highest peak at only 267 meters (880 feet) and the island is eight square kilometers (three square miles) in area (GSVG, 1983b) (Figure 3). There are no public wells on Canouan and I am not aware of any private, brackish wells. Canouan has two community catchments with a very limited number of standpipes located downhill from their source. There is no obvious town center on Canouan, which lacks a public market and concentrated commercial area such as those found in Bequia and Union. Most people identify their residences as being in small neighborhoods with colorful names such as "Happy Hill." Students from Canouan who are eligible to attend secondary school must travel to Bequia, Union or St. Vincent to do so. The island has had public electric service for only one year but most homes appeared to be connected to the grid. Land transportation is accomplished by foot or private vehicles and I saw no evidence of mini buses or taxis. A small airstrip, south of the area on the west coast where the majority of people have settled, serves primarily the Canouan Beach Resort, one of two exclusive resorts providing employment to islanders. It can be reached overland via jeep roads. Many visitors to the resorts arrive by yacht.

Mayreau is the smallest island in this study with an area of only two-and-one-half square kilometers (one square mile) and a peak elevation of 85 meters (280 feet) (Figure 4). As visitors to Mayreau climb along the very steep hill from Saline Bay on the west coast to the village, Old Wall, a colorfully painted sign, complete with population total, road map and location of restaurants and shops, welcomes them to the island. Old Wall, located near the top of the second highest hill, Station Hill [elevation 80 meters (262 feet)] (GSVG, 1983c), has two community catchments. Other than 21 acres acquired by the St. Vincent

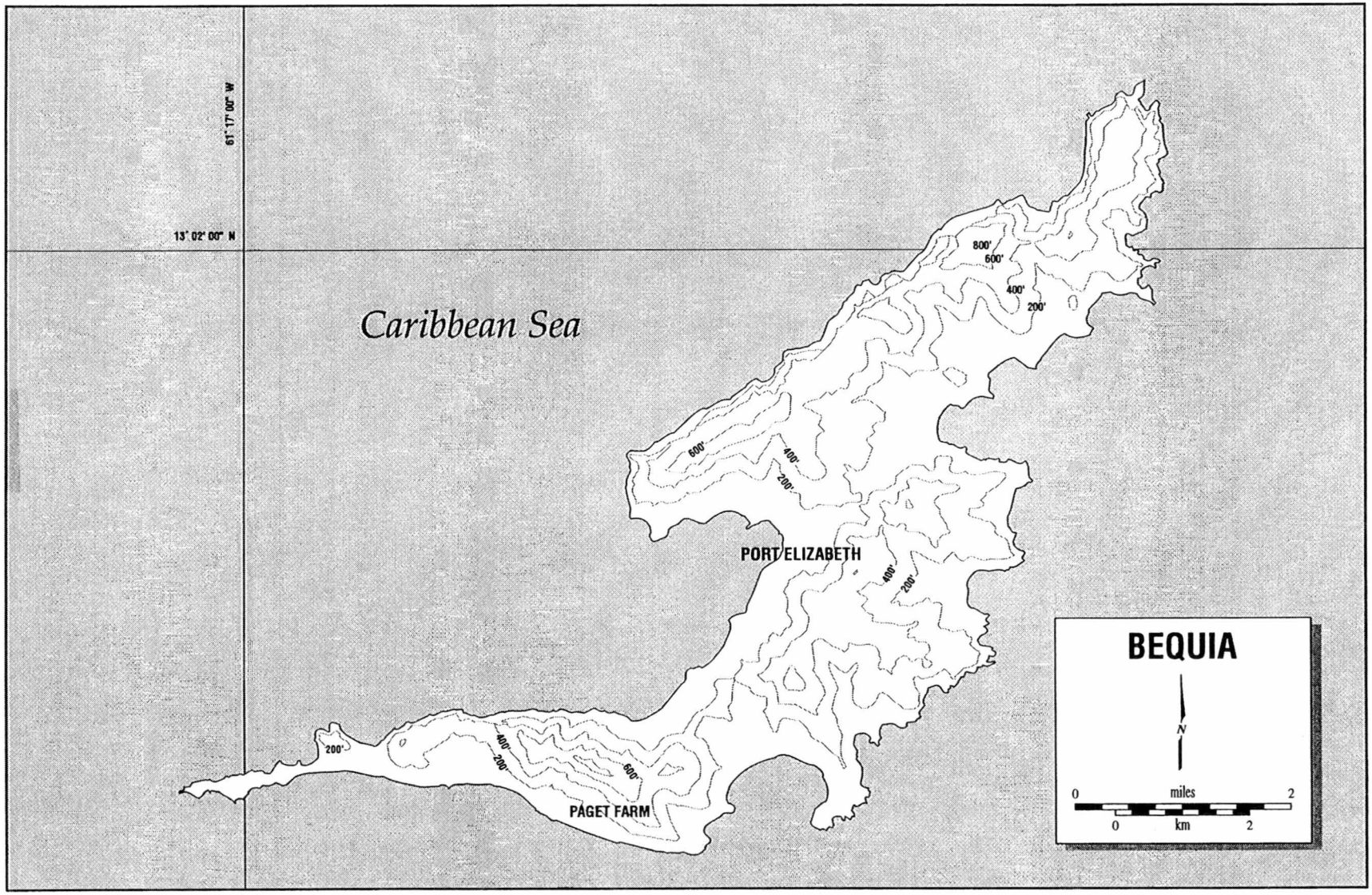


Figure 2. Bequia, St. Vincent and The Grenadines.

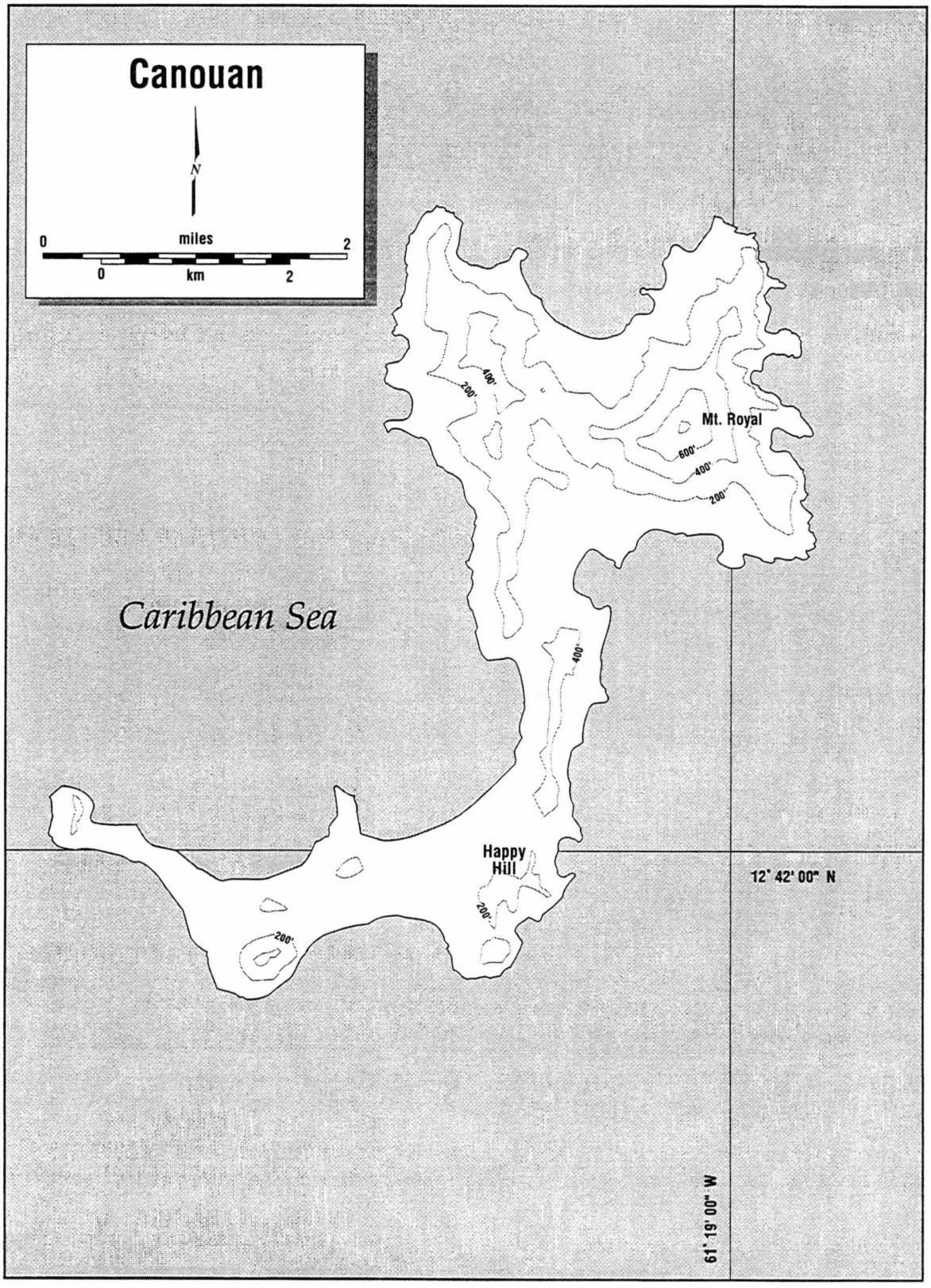


Figure 3. Canouan, St. Vincent and The Grenadines.

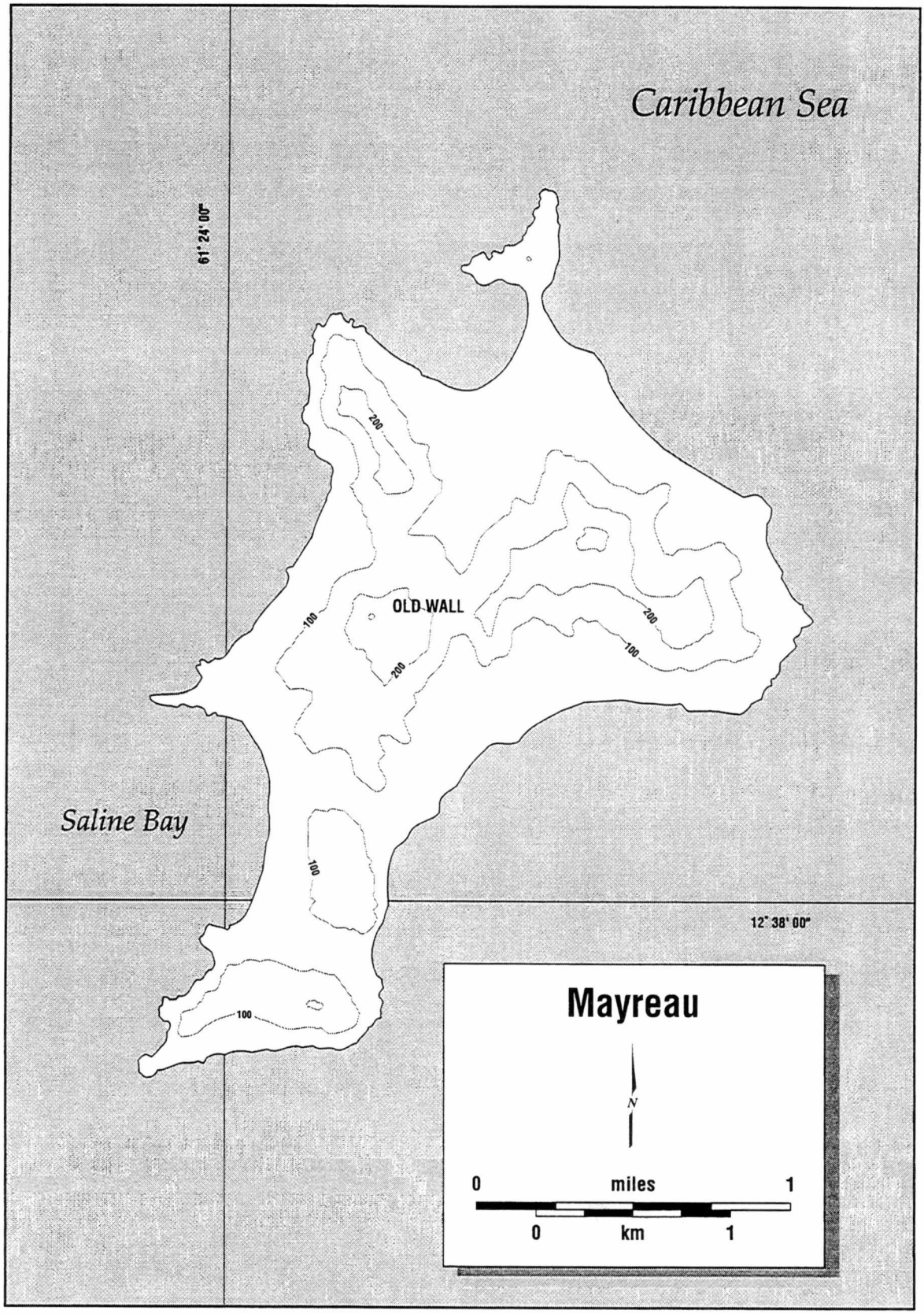


Figure 4. Mayreau, St. Vincent and The Grenadines.

Government in 1986 and occupied by the one village and, an additional 22 acres that are Canadian owned, the island is privately owned by the descendants of the St. Hilaire family that fled France during the Napoleonic Wars (DeSilva, 1995). Like Canouan, Mayreau has no public transportation and lacks a market and secondary school. There are only two motorized, jeeplike vehicles on Mayreau. Both are owned by the Saltwhistle Bay Resort on the north coast, which provides its water needs with a paved hillside catchment. Mayreau has no airstrip, wharf or public electric power, although businesses, a resort and a very limited number of private homes (perhaps two or three) generate power for their individual uses with diesel generators. I observed two apparently functioning windmills, presumably for electric generation. From what I could gather during my short stay, I believe that when there is the need to buy household supplies typically a family member will make the boat trip to St. Vincent. Because there is no wharf in Mayreau, people and goods arriving on the ferry must reach shore on small motor launches. Goods are then moved up the cement paved road with a 40% grade to town by donkey or people power.

The highest point on Union is Mount Taboi, 304 meters (999 feet), and the island's size is 10 square kilometers (four square miles) (GSVG, 1983d) (Figure 5). The only public reservoir is in Ashton, so the residents of Clifton must travel two and one quarter kilometers to collect fresh water when needed. A second government reservoir, in Clifton, primarily supplies a clinic's water needs (CCC, no date). Union Island has a relatively busy, albeit small airport, the Bougainvillea, with one landing strip that is too small to accommodate jet aircraft. Most of the residents live in the eastern two-thirds of Union and around the two major settlements, Clifton and Ashton. Clifton is the more commercialized village with a busy port, the airport and several small retail businesses, while Ashton is a more residential area. The island is totally electrified and most homes appeared to be connected to the grid at the time of my visit. This is a bustling island with a good deal of construction of new residences, guest houses and, a new 300 ship marina in Ashton, designed to lure additional tourists. This increased construction activity has led to an influx of people from St. Vincent. Two resorts provide service employment. One is situated on Union; the other, Palm Island Resort, is slightly more than 1.5 kilometers off-shore from Clifton Harbor.

Options for Water Acquisition in the St. Vincent Grenadines

The options for acquiring potable water in the study area are limited by the seasonality of rain, the small size and the topography of the islands. In this section I will briefly describe the options for acquiring water on small dry islands and explain the pros and cons of each, leading to the conclusion that, for now, rain water harvesting is the best option for acquiring water in the St. Vincent Grenadines.

Rainfall amounts in the Grenadines are controlled by three major factors, easterly waves, island size and elevation. Easterly waves are the source of most of the rain in the Grenadines. These are large troughs of low atmospheric pressure, believed to form over West Africa, that pass over the area mostly between May and November. If these easterly waves travel quickly they will bring little or no rain, but if they travel

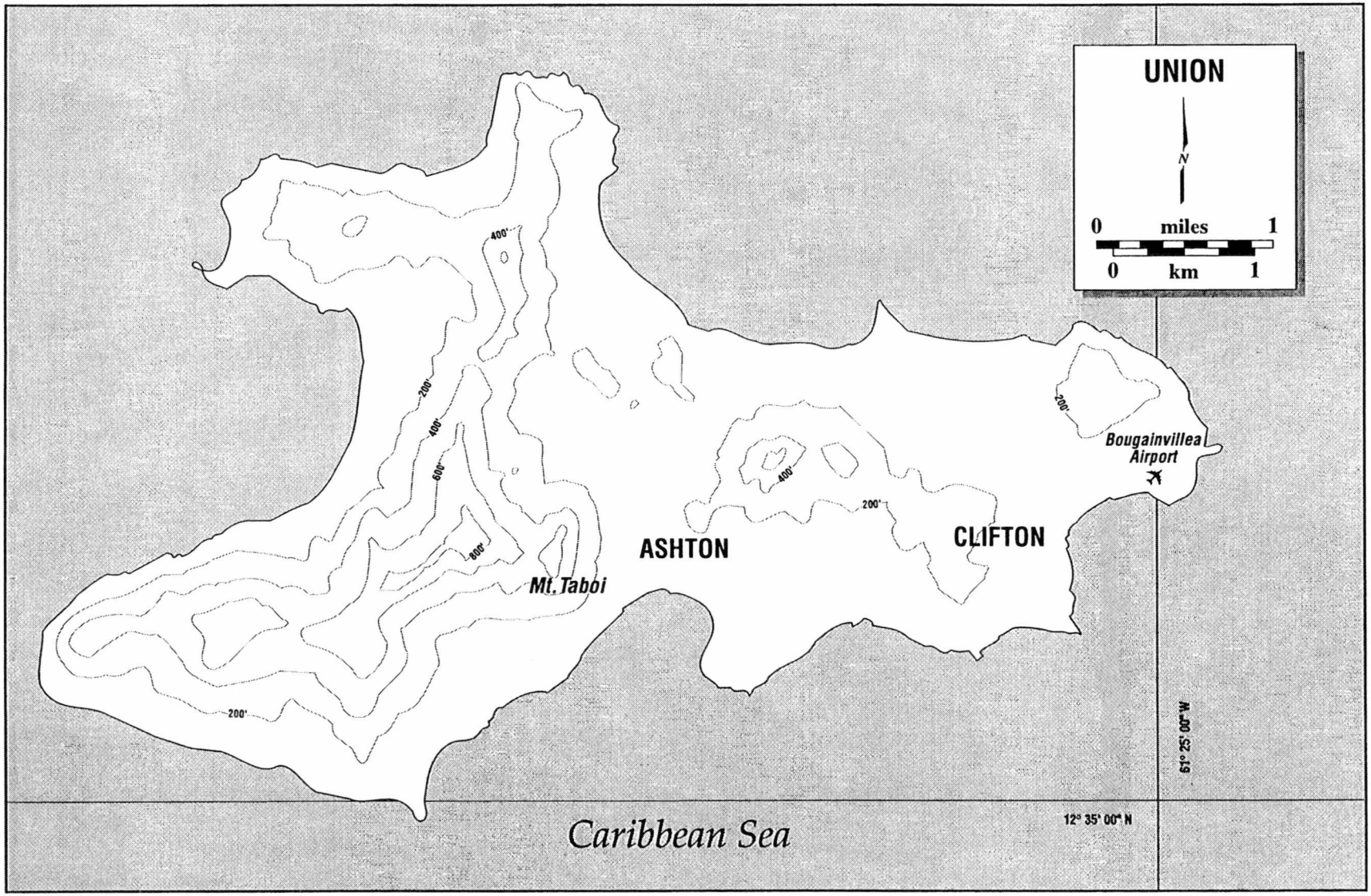


Figure 5. Union, St. Vincent and The Grenadines.

more slowly, as is the usual situation, showers may fall over a period of a day or two (Macpherson, 1980). All of the islands in this study are small, low volcanic islands. Orographic rain clouds are formed as moist trade winds rise up and flow over high islands (Falkland, 1991). However, this is not a major factor in the Grenadines because they are not high enough to cool the warm air sufficiently to cause condensation. Although all public catchments in the Grenadines are built on hillsides to take advantage of the any potential orographic effect, the slopes also efficiently deliver the rain water into large concrete water tanks at their bases. In addition, paved catchments are constructed on slopes too steep to be used for other purposes such as building and farming.

Relief and size also have a considerable effect on the potential for natural water storage in the ground or on the surface. Very small volcanic islands, less than 100 square kilometers, are unlikely to have a fresh water lens or perennial surface water bodies (Falkland, 1991). This is primarily because most rain falling on steep hillsides with relatively impermeable surfaces quickly runs off. Ponds and streams form in depressions following rain events but are ephemeral and will dry up as the rate of evaporation exceeds the rain. Surface water, therefore, is not an optional water source in dry months.

Desalinization

Desalination of sea water or brackish well water is a potential source of potable water for small tropical islands. Although desalination is not a new technique and interest in it is high, ongoing research for improving the desalting of water has not found a system that is affordable for communities with little cash flow.

Mechanically uncomplicated, solar desalination vaporizes water by utilizing the sun's heat, producing a demineralized condensate. A solar powered still was already in use in 1872 at Las Salines, Chile to purify water for mules working a mine (Headley, 1993). One solar still has been designed to incorporate the collection of rain water, increasing its efficiency (UN, DESA, 1970); but all solar technology remains expensive. Capital costs for the installation of a solar still in 1970 U.S. dollars were about US$1.00 per 0.093 square meter and production costs at that time ranged from US$66 to $132 per 1,000 liters of fresh water produced (UN, DESA, 1970). Falkland (1992) estimates the daily output of solar stills in the humid tropics to be about three liters per square meter. This output is small relative to other desalination techniques, so providing sufficient water requires large, hence expensive, solar units.

Thermal desalination processes that depend upon fossil fuel to supply energy include the distillation processes (evaporation and condensation) of multi-stage flash, multiple effect and vapor compression. Mechanical processes that pass water through a membrane to remove minerals, including reverse osmosis and electrodialysis are also powered by fossil fuel (Falkland, 1992). Certain Caribbean governments that are relatively well-off economically, notably Aruba, the U.S. Virgin Islands and Bermuda, (Falkland, 1992) and a handful of resort hotels in the St. Vincent Grenadines utilize these desalination processes (CCA,

1991; Johnson, 1995), which are quite sophisticated and costly to install, operate and maintain. They require a reliable source of spare parts and chemicals as well as skilled personnel for operation and maintenance (Falkland, 1992). Cost in Anguilla for reverse osmosis desalination of brackish water was US$5.80 per 1,000 liters of fresh water in 1988. Desalination of sea water by reverse osmosis and multi-stage flash ranged between US$1.10 to $4.81 per 1,000 liters at the same time in other small island countries (Falkland 1991).

As yet, desalination of brackish or sea water is not a financially viable option in the St. Vincent Grenadines. Relatively flat land, suitable for the installation of solar stills, is at a premium on all the Grenadine islands. With no cheap energy available, mechanical desalination plants are unsuitable due to the high cost of installation and operation. The economy of St. Vincent and the Grenadines is somewhat smaller than others in the Organization of East Caribbean States, with a gross domestic product for the entire country of less than US$56,000,000 (EC$150,000,000)[1] in 1987 (CCA, 1991). The annual per capita income of St. Vincent and the Grenadines, slightly more than US$1,000 per year in 1987, is among lowest in the Eastern Caribbean (CCA, 1991). Because young people who leave the country to attend college and attain technical skills rarely return, the lack of highly trained personnel to operate these plants is also a problem (Mason, 1995).

Water Importation

Several Caribbean hotels import bulk shipments of water on a regular basis as a sole source of potable water, while other hotels and several islands import water only during times of shortages. Water can be imported by sea transport on barges or tankers and via submarine pipelines, and many islands including Bahamas, Aruba, Grenada, Antigua, St. Martin, Curacao and the St. Vincent Grenadines have needed to do so (Blackman, 1987; Haan, 1987; Falkland, 1992; Lewis, 1994; Browne, 1995). The quality of such transported water may be suspect because of the questionable cleanliness of the container, and only some ships are set up to allow for testing prior to acceptance of the water (Blackman, 1987).

The cost of bulk water importation depends on the distance between the source and destination and on the price charged by the provider. The island of St. Thomas in the U.S. Virgin Islands paid US$4.65 per 1,000 liters of water imported from Puerto Rico in the early 1980s. The price of Puerto Rican water to other small Caribbean islands during the same time ranged between US$1.50 to $5.70 per 1,000 liters (Falkland, 1991). Water exported from Dominica to islands within 150 miles cost from US$1.60 to $2.60 per 1,000 liters (Blackman, 1987). Although water is occasionally imported to all of the Grenadine islands, the high cost of bulk imports of water would prohibit the government's dependence on it as a sole or routinely scheduled water source for the Grenadines.

---

[1] An exchange rate of EC$2.67 per US$1.00 is used throughout this thesis.

Amerindian Water Procurement

An Amerindian technique for tapping into fresh ground water lenses or sub-surface solution channels has recently been explored by Schultz (1996) on the Grenadian Grenadine island of Carriacou, which is topographically similar to the St. Vincent Grenadines. Schultz believes that Amerindians used bottomless clay pots to line shallow wells in the Caribbean. The pots were placed into the well shaft at intervals during excavation to prevent the walls from caving in. A modification of this pre-Columbian technique is still being used by some local people in Carriacou to tap into fresh ground water in level areas near the coast, where wells, lined with bottomless oil drums, collect groundwater for livestock year-round and for domestic use only when rain water supplies have become depleted. However, even when the mineral content of well water on Carriacou is within the range that is acceptable for human consumption, residents prefer the taste of collected rain water (Schultz, 1996).

According to R. Dijon's theory, exploitable fresh water lenses are generally not found beneath very small islands, less than 100 square kilometers in area with widths no greater than three kilometers (Falkland, 1991). It is highly unlikely, therefore, that a fresh water lens with sufficient yield to supply community needs is present below any of the Grenadines in this study due to their small size; although, as in Carriacou, which is only 34 square kilometers, extraction of small amounts of water from shallow wells may be possible in those areas of the Grenadines where level coastal zones are sufficiently wide.

Rain water Harvesting

For more than 4,000 years humans have purposely built systems for the collection and storage of rain which was then used, for domestic purposes, livestock and for irrigation (Hadwen, 1987b). Such catchments are still being built throughout the Caribbean. For example, roof catchments were the only form of water supply on more than 20 islands of the Bahamas in the late 1980s (Hadwen, 1987a) and rain water harvesting systems have been required for all buildings in the Bahamas by public ordinance since 1869 (Latham & Schiller, 1987). Latham and Schiller (1987) have established that rain water harvesting was the principal source of potable water in the Mediterranean area as early as the sixth century A.D. and that it is a common water procurement strategy in Europe, Africa, Asia, Australia, the Caribbean, the Americas and, Atlantic and Pacific island regions.

The rain water collection mechanism and size of the storage vessel vary with the intended final use of the harvested rain. In the Caribbean, large concrete tanks store water collected from paved hillsides, abandoned runways (Falkland, 1992) or from the roofs of large public buildings (I saw schools in the St. Vincent Grenadines and in Carriacou in 1994 where roofs and ground catchments had been combined to feed one large tank).

The initial cost of construction of rain water harvesting systems that use roofs for the catchment surface (roof catchment systems) depends on the availability of labor and materials and costs of shipping

and project administration. The SVGCC/CCC Project was able to supply the islanders in this study with moderately priced water systems. For example, whereas a ferrocement tank built in Botswana or Kenya in 1984 cost US$26.00 per 1,000 liters of storage (McPherson & Gould, 1987), in Zimbabwe (date unknown) the cost was only US$10.00 per 1,000 liters (Hadwen, 1987b). The cost using the "Friends' Training Center" construction method was US$22.00 per 1,000 liters (Pacey, 1986) and in 1989 a pre-built tank cost US$75.00 per 1,000 liters (Reynolds, 1990). Cost for a tank and necessary guttering in the Cayman Islands was US$22.50 per 1,000 liters, and for a large capacity (176,000 liter) reinforced concrete tank it was US$18.00 per 1,000 liters in 1989 in the Turks and Caicos (Astwood, 1990). The SVGCC/CCC Project final cost for materials, shipping and contracted labor was US$614.22 each (US$46.03 per 1,000 liters) (CCC, no date).[2] The relatively high costs of these tanks may be attributed to high shipping prices due to the relative isolation of the islands from major sources of needed materials.

Roof catchments systems are simply designed and easy to maintain and appear to be a very appropriate and economical alternative water strategy in areas, such as the Grenadines, with adequate rainfall and where ground and surface water are limited or of suspect quality, or where a distribution system is not physically or economically feasible. Once rain water harvesting systems are properly constructed, routine maintenance and some repairs can generally be carried out by householders. So, for now, the collection and storage of rain by household and community catchments appear to be the most reasonable methods for acquiring potable water in the St. Vincent Grenadines.

---

[2] These figures are based on the Expenditure Statement presented by the SVGCC in the *Final Report* and a 13,344 capacity. Original figures as given in EC currency for construction of 50 ferrocement tanks in the Grenadines are:

Material purchase	$51,628.40
Project transport costs	2,350.00
Combined labor	28,020.00
Total	$81,998.40

Total project costs including administrative expenses were somewhat higher.

CHAPTER III

THE FERROCEMENT WATER TANK PROJECT

The CCC Project Development

In this section I introduce the Caribbean Conference of Churches (CCC) and the St. Vincent and the Grenadines Christian Council (SVGCC), and discuss the events that led to the Low-Cost Ferrocement Water Tank Construction Project in the St. Vincent Grenadines. I then describe the structure of the project and chronicle its progress.

The CCC, an ecumenical organization based in Bridgetown Barbados, was formed between 1971 and 1973 to bring together churches in the Caribbean "to work more closely together for the alleviation of social, economic and political hardships in the region" (Davis, 1982). CCC was the first regional ecumenical association to promote the involvement of the churches in issues of regional economic development, activism, political empowerment processes and peace (Deere et al., 1990). Through its Development Programme, the CCC has been involved in a number of activities that promote economic growth, social justice and self-reliance of Caribbean people (Davis, 1982). For example, the CCC has been actively involved in helping to alleviate the water problems in the Grenadines since 1974, when it provided financial support to the SVGCC for the construction of the public water catchment in Mayreau (CCC, no date).

The SVGCC, a national organization composed of clergy from St. Vincent and the Grenadine islands, was established to promote cooperation between the various religious sects of the country in addressing local social issues. The organization, which is based in Kingstown, St. Vincent, is administered by lay volunteers.

In its effort to improve the lives of needy people in the Caribbean and seeing the need for additional water tanks in St. Vincent Grenadines, the CCC made a successful proposal to the Canadian International Development Agency (CIDA) in 1984, eventually receiving EC$101,300 (US$37,940)[3] to fund this project. A copy of the CCC Project Proposal is given in Appendix A. The concept of this project and the background work began in the early 1980s. The tank design was developed by a U.S. Peace Corps Volunteer, B. H. Robinson (no date), in St. Vincent, who also authored an easy to understand construction manual. As part of an earlier CCC project, designed to introduce and promote ferrocement technology, masons had been trained and demonstration tanks had been built in Barriouallie, St. Vincent and in Bequia, Canouan, Mayreau and Union ("Technology Transfer...," 1982). The 1984 Canadian funding provided for the construction of 10 tanks each in Bequia and Mayreau and 15 tanks each in Union and Canouan (CCC,

[3] This figure was given as the total disbursement of funds to CCC and SVGCC in the SVGCC "Final Report."

no date). No funding was provided for guttering or roof repairs, both crucial elements in the catchment aspect of rain water procurement. The planned project duration was one year (CCC, no date), and the CIDA agreement required a final or interim report by March 31, 1985 (Canadian High Commission, no date).

The ferrocement water tank design used for this project has a water storage capacity of 13,344 liters, considered by CCC (no date) to be an adequate supply for an average sized household in the St. Vincent Grenadines. I found no documentation on how or if this capacity had been evaluated for sufficiency over time using consumption and rainfall amounts and patterns.

The SVGCC/CCC Project was designed as a self-help project with recipients providing some of the labor, some tank construction materials, gutters and maintenance. Regional administration of the water tank project was undertaken by the SVGCC, which was responsible for the disbursement of project funds for material purchases and for appointing the volunteer oversight committees who were organized on each island (Paulsen, 1984).

Volunteer oversight committee members were chosen directly by the SVGCC or, as in the case of Bequia and Mayreau, by individual community members who were chosen by the SVGCC (Paulsen, 1984). Local oversight committees were responsible for coordinating and monitoring construction, making payments for shipping, labor and the delivery, storage and inventory of materials, and local publicity and choosing potential tank recipients (Paulsen, 1984; CCC, no date). The names of potential recipients were to be submitted to the SVGCC for final approval. Oversight committees were also to encourage and facilitate local in-kind contributions of labor and materials for those recipients who were deemed incapable of providing these themselves (Paulsen, 1984).

The proposal stated that recipients would be chosen based on their need, their willingness and ability to supply sand, rocks, gravel and some of the labor, and the practicability and willingness of two or more households to share the use of a tank (CCC, no date). The project budget provided for the purchase and transport of tools, cement, form work and reinforcement materials and for technical expertise and supervision by trained masons who provided guidance and labor (CCC, no date).

Local committees appear to have had some autonomy in developing specific guidelines for eligibility. According to what appears to be the first progress report submitted by the SVGCC, dated October 15, 1984, the Bequia committee modified the application form. In Union, no application form was used. Instead, applicants made themselves known to committee members who discussed their eligibility at committee meetings. Tank recipients were chosen based on the perceived need. Such factors as the proximity of the applicant to a public supply or a neighbor willing to share their tank water and the current employment status of the applicant were used in choosing recipients (Browne, 1995). The application procedure for Canouan and Mayreau remains unknown to me.

Masons were to receive US$210 (EC$560) per tank (CCC, no date) but in some cases the trained masons were unavailable to supervise the tank construction or refused to work for the allotted payment. They were replaced by skilled masons who agreed to follow the methods described in the construction manual (Paulsen, 1984). It is my understanding that a supervising mason and his chosen laborer(s) were to be present and involved in the building of each water tank. The mason from Union and his helper worked on the water tanks in Mayreau and were provided lodging there paid for from separate funds supplied by the SVGCC (Mason, 1985).

Project Implementation

In this section, I do my best to chronicle the SVGCC/CCC Project implementation because such a history does not exist elsewhere and because it may be helpful to new projects in other locations.

The project was started in Bequia, which can be reached via a one hour ferry ride, because its close proximity to St. Vincent afforded easy monitoring of project activities. It was deemed useful to have close observation during the early stages of the project in order to evaluate implementation procedures and to make necessary changes. In Bequia, the oversight committee was formed and applications were distributed in October, 1984. Additional training in basic techniques of ferrocement was provided to masons in Bequia by David Webb of the British Research Engineers (SVGCC, 1984). Tank recipients were chosen and construction of all ten tanks was completed prior to July 1985 (SVGCC a, no date).

The breakdown of the government vessel which was to provide for the transport of materials and tools caused delays in the project. This problem was partially resolved by the project coordinator, Liley Cato, Executive Secretary of the SVGCC. Mr. Cato made alternate arrangements to ship the necessary materials to Bequia, Union and Canouan (Mason, 1985).

Arrangements for the shipment of materials to Mayreau were made by the Oversight Committee Coordinator for Mayreau, Ella Roache, for delivery by a smaller local boat. Recipients arranged for storage of the materials and, because Mayreau has no wharf, they arranged for the transport of materials to shore from the larger vessel (SVGCC a, no date). This resulted in an increased transport cost that was partially offset by not shipping the essential tools needed for tank construction. Instead, these were supplied by local residents. Tank construction began in April, 1985, and seven of the ten tanks were completed in time for the rainy season (SVGCC a, no date) (which may start as early as June). All ten tanks were completed by July, 1985 (Mason, 1985).

The wharf at Canouan had not yet been built during the time of the project implementation; so, Canouan tank recipients were also required to transport construction materials to shore from the delivery ship. An agreement was made with the mail vessel, "United Knowledge," to make a special trip to deliver

all necessary materials to Canouan for US$225 (EC$600).[4] A minor administrative delay occurred when the committee chairperson, Thornhill Sandy, was off island and unable to sign the necessary documents to withdraw funds from the project account. Tank construction commenced in mid-May, 1985, and eight tanks were completed in time for the rainy season (SVGCC a, no date). All 15 were completed by July, 1985 (Mason, 1985).

In Union, the transport of materials and tank construction were put off until the mason, who was constructing SVGCC/CCC tanks in Mayreau, returned to train the masons and supervise construction in Union. The Union oversight committee members were able to assume responsibility for making the arrangements for storage and surface transportation of materials.

After his visit to the Grenadines in July, S. Conrad Mason reported that the foundations for all 15 tanks in Union had been dug and that construction was due to start on July 16, 1985 (Mason, 1985). The hope that construction of all tanks in Union, the final project site, would be completed by September, 1985 (SVGCC a., no date) was not realized and it was not until late November to early December that all tanks were completed (SVGCC b., no date) and the SVGCC/CCC Project had fulfilled its objective of building 50 water tanks in the St. Vincent Grenadines. The project took approximately one year and nine months from start to finish.

Roof Catchment Systems: An Overview

The SVGCC/CCC Project evaluated in this thesis is a form of rain water harvesting. This section summarizes details of roof rain water harvesting to provide a broader context within which to evaluate the SVGCC/CCC Project.

Because roof catchments are the most common rain water harvesting systems (Hadwen, 1987b) and because my study focuses on this application, the following discussion is limited to these systems. Roofs of homes fitted with some form of guttering serve as collection surfaces to supply household use, with a wide range of vessels used for storage. Where money permits, homeowners have large tanks constructed of concrete, bricks or stone either above or below the ground (Hadwen, 1987a; Yoganarasimhan, 1987). Today, large tanks are often built into a hillside under a building, with reinforced concrete floors and roofs. Walls are constructed of mortar-filled concrete blocks that are covered on the interior with mortar approximately 1.5 centimeters thick (Waller, 1982). One such tank, its roof serving as a porch where I enjoyed a soft drink and conversation in Union, held more than 130,000 liters of water. Smaller storage containers are fabricated from a variety of materials such as corrugated galvanized metal, fiberglass, wood,

[4] Project transportation costs were not broken out in the budget contained within the original proposal. The report submitted by the SVGCC states that the incurred transport costs to Mayreau and Canouan were increased over the cost that had been negotiated for shipment on the government vessel. Final costs incurred for transport of materials to all four islands were US$610.

ferrocement, bamboo reinforced cement and clay jars. Discarded buckets and 200 liter oil drums, cheap and durable, are commonly used but are too small to supply sufficient water for the long run (Hadwen, 1987b). I also saw many rigid, black plastic barrel-shaped 1,500 liter water tanks at distributors in the Grenadines and recently installed at homes. On the basis of their size, I estimate that the larger tanks I saw at the docks and warehouse yards have a 5,500 liter capacity. Some people use the black plastic tanks only for supplementary water storage, and many with whom I spoke preferred the taste of water from the cement or concrete water tanks and reserved the water from the black plastic tanks for non-potable uses.

Tanks or cisterns that are engineered for household rainwater storage have an inlet and outlet, a clean-out access and an overflow device (Desa, 1981; Schiller, 1982; Pacey, 1986; Chindaprasirt, Hovichitr & Wirojanagud, 1987; Lee et al., 1987; Astwood, 1990; Reynolds, 1990; Robinson, no date). To improve water quality, certain designs include a water filtering device at the inlet, using gravel, sand or local materials such as coconut husks as the filtering medium and a drain valve located lower than the outlet for the removal of the bottom water when cleaning is needed (Pacey, 1986; Yoganarasimhan, 1987). With or without a filter, diversion of the initial runoff from the first storm following a dry spell (first flush) is recommended to ensure that dust and/or debris, which can contaminate the water and which may have collected on the roof and in the gutters, are kept out of the storage tank (Johnson, 1982; Pacey, 1986). Rather than install elaborate devices to divert this initial flow and filter incoming water, most projects simply suggest that householders manually divert the initial flow and screen the inlet to prevent large debris from entering. Covering the outlet opening with fine screen mesh and sealing around the hatch cover and around the inlet well will keep out small animals and insects such as mosquitoes (Pacey, 1986).

Roofs constructed of galvanized sheet metal provide the most efficient collection surface (Pacey, 1986). Tile, cement, bituminous paper and even thatched roofs can be used, however, the water collected from thatched roofs will be discolored and easily contaminated (Johnson, 1982). Gutters need to be of sufficient size to collect all or most roof runoff during heavy storms. Pacey (1986) recommends 200 mm diameter gutters adequately supported to hold the weight of water from heavy rains. Gutters can by made from wooden planks nailed together in a V-shape, bamboo, metal or plastic. However, plastic (PVC) gutters are not generally recommended as they become brittle and crack from exposure to sunlight (Falkland, 1991). Several appropriate technology centers even have demonstrated the use of discarded tin cans riveted together to form gutters. Whatever the guttering material, a length of gutter or a large diameter section of pipe is used for a down spout delivering water from the gutters to the tank. The outlet, or water tap, overflow and drain are generally constructed with standard plumbing fixtures and piping. The clean-out hatch opening is adequately sized for access by an adult to perform repairs and periodic maintenance of the interior of the tank. A range of materials, such as wood, galvanized metal or concrete, can be used to construct a snugly fitting covering for the hatch.

Because falling rain is pure, except in highly industrialized areas, the quality of harvested rainwater is primarily dependent upon the condition of system components (Schiller, 1982). Johnson (1982) believes that when harvested and stored under safe conditions, water does not often require any treatment prior to domestic use. If all tank openings are well sealed or screened any bacteria carried by water flowing into the tank will tend to naturally die off after several days, especially in warm climates (Pacey, 1986; Pinfold et al., 1993). Some bacteriological contamination of water from roofs has been found wherever water quality tests have been conducted, but it is usually very slight (Pacey, 1986). Where coliform bacteria and turbidity (a scattering of light indicating suspended matter in water) have been measured in the East Caribbean higher levels have been detected in poorly maintained systems (Haebler & Waller, 1987). If the quality is suspect, the tank water may be treated lightly with chlorine (Johnson, 1982), iodine (Skoda & Reynolds, 1993) or by boiling before use. A gentleman with whom I spoke in Mayreau, however, cautioned against the use of chlorine in the tank, remarking that it was difficult to control and to measure the concentration because the quantity of tank water fluctuates constantly, especially during the rainy season. Most people with whom I spoke in the Grenadines who treat their tank water, do so by keeping small, live fish in the tank to eat mosquito larvae. Other traditional uses of indigenous plants and natural materials to treat small quantities of water have been common for many years in some countries (Johnson, 1982).

Proper construction techniques and diligent maintenance are key to maintaining good quality water and efficient operation of roof catchment systems. Routine maintenance tasks are necessary for all system components. Pacey (1986) and Falkland (1991) recommend that system components be cleaned once every six to twelve months, including removing debris from the tank bottom at the end of the dry season when the tank is nearly empty. This can be accomplished after first removing the bottom water and scrubbing the interior with a solution containing vinegar, baking powder or chlorine bleach with water followed, after 36 hours, by rinsing with clear water. Additionally, it is important that roofs and gutters be cleaned on a regular schedule to discourage the growth of moss where flies may lay eggs, allowing larvae to be washed into storage tanks (Waller, 1982), that roofs and gutters be kept free of bird droppings and that inflow filters be cleared of leaves and other debris (Pacey, 1986). System efficiency and longevity will be aided by frequently inspecting the tank, gutters, roof, inflow pipes, screening and mosquito netting. Leaks can be repaired when the tank is empty, other components need to be replaced or repaired as needed. Thus, simple routine tasks to a well constructed system will ensure maximum water collection, storage and quality.

Ferrocement technology, a relatively new way to construct rainwater cisterns, was developed in the 1950s (Pacey, 1986) and requires fairly specific construction techniques. In order to analyze the current physical conditions of the SVGCC Project's tanks, I will outline these details in the following section and also will present the range of construction costs and sizes of ferrocement water tanks.

Rainwater Cisterns Constructed Using Ferrocement

As defined by the American Cement Institute in 1982, ferrocement is a thin-walled concrete fabricated of cement mortar reinforced with closely spaced layers of relatively small diameter wire mesh. Ferrocement construction is a low-level technology that is labor intensive and does not require heavy machinery. Construction skills can be learned quickly and ferrocement is suitable for construction of structures such as water tanks. Ferrocement water tanks have been in use in New Zealand since the late 1960s (Lee et al., 1987). Concrete and ferrocement are preferable to galvanized iron for water tank construction on small islands, such as the Grenadines, where a highly corrosive environment is created by the warm air and salt spray (Skoda & Reynolds, 1993). Tanks fabricated of corrugated metal may be cheaper initially, but they have a short life-span (Pacey, 1986) while concrete block cisterns, which have a very long life, are quite costly and often can not be afforded by Grenadinians (CCC, 1982). Construction costs for ferrocement tanks vary as demonstrated in the previous section. However, despite the high initial cost to construct individual ferrocement tanks, they are the cheapest alternative almost everywhere to provide a durable household water supply (Pacey, 1986).

Ferrocement water tanks have a cylindrical shape with domed tops and can be built upon a concrete foundation (Figure 6). Tanks range in size from 4.5 to 20 cubic meters (Desa, 1981; Lee et al., 1987) but most commonly between 10 to 13 cubic meters (Desa, 1981; Pacey, 1986; Hadwen, 1987b; McPherson & Gould, 1987; Reynolds, 1990; Skoda & Reynolds, 1993). For this study I converted from imperial units, as given in the original design specifications, to metric and measured the tanks during my 1995 visit. The wall height is 1.83 meters. The diameter is 3.05 meters and the actual capacity is 13,344 liters, which is somewhat less than the 15,911 liter (3,500 gallon) capacity described in the instruction manual. The tank sits on a 3.66 meter square foundation comprised of 15 centimeters of sand and stone covered by cement pad.

Tanks constructed in the SVGCC/CCC Project follow the standard ferrocement design criteria regarding components, screening and sealing, with an overflow spout molded out of the ferrocement at the wall-top seam. The 0.61 meter square hatch opening is framed with 5 centimeter by 5 centimeter pine boards and fitted with a cover fashioned from pine and galvanized sheeting. The water tap is made from standard 1.3 centimeter galvanized piping with an attached spigot. Three 90 degree elbows are used to form a u-shape in the outlet pipe between the interior and exterior of the tank.

In most designs, the foundation doubles as the tank's base (Pacey, 1986; Skoda & Reynolds, 1993; Robinson, no date), although the base of the water tank may be set directly on the ground (Desa, 1981). Experimental tanks built in Singapore have a separate tank base on top of the foundation, isolating the tank from the foundation with an impermeable layer of polyethylene in case the tank needs to be moved to a new location after it is built (Lee et al., 1987). Recommendations for the base thickness range between 30 to 80 millimeters (Pacey, 1986; Lee et. al, 1987) but reinforcing the foundation to eliminate leakage is

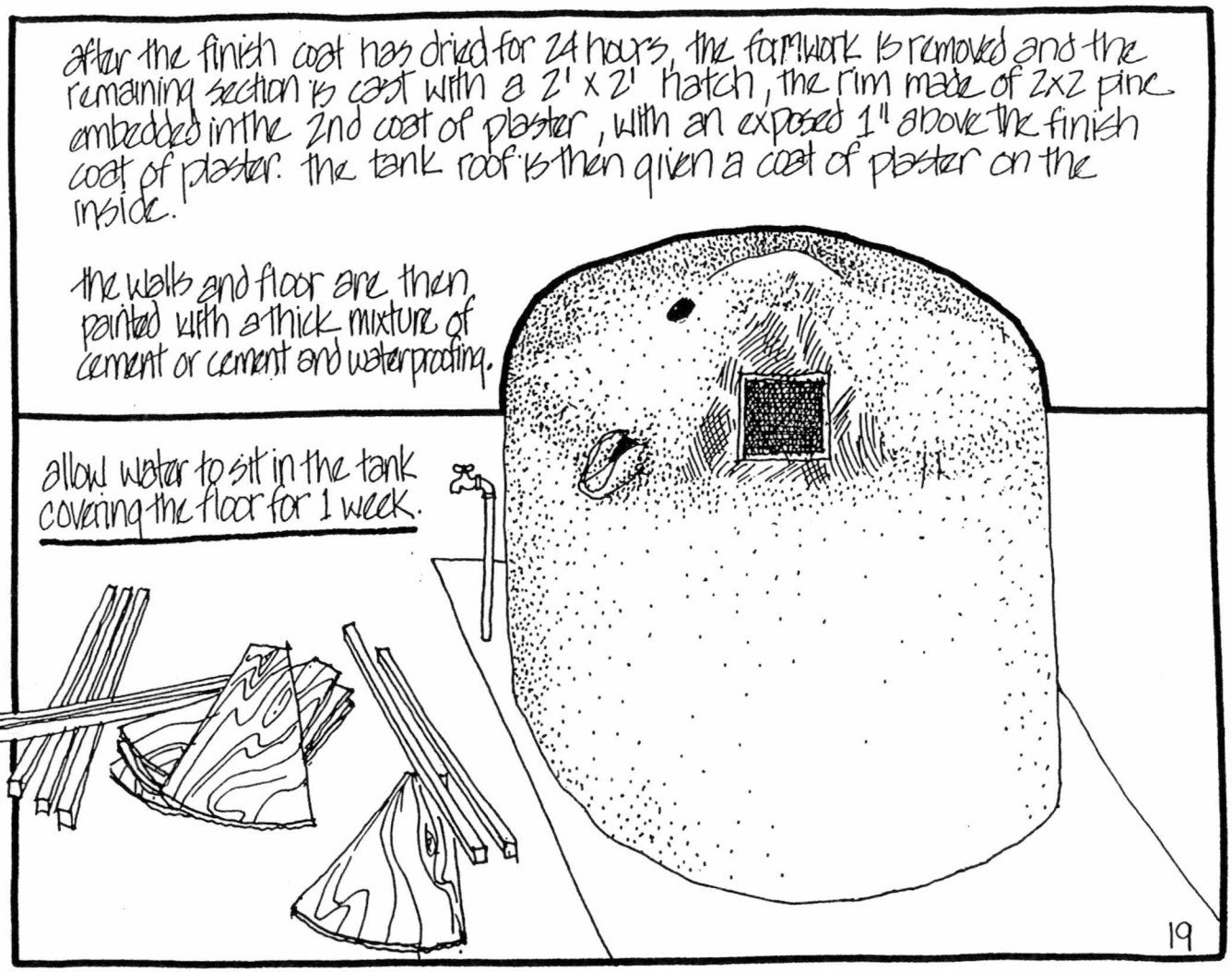


Figure 6. SVGCC/CCC ferrocement water tank. Copyright ® Christian Action for Development in the Caribbean CADEC/CCC. All Rights reserved. Used by Permission (Robinson, no date).

recommended (Skoda and Reynolds, 1993) The SVGCC/CCC built tanks, designed by Robinson, were assembled on an unreinforced foundation 76 millimeters thick.

Using forms assembled from corrugated galvanized sheeting and plywood, tank walls, base and roof are fabricated by layering the cement mix over the reinforcing framework (Pacey, 1986; Hadwen, 1987b; McPherson & Gould, 1987; Lee et al., 1987; Gould, 1987; Reynolds, 1990; Skoda & Reynolds, 1993). The SVGCC/CCC design calls for galvanized hex mesh wire (0.254 cm) with 0.65 cm gauge steel wire be wrapped around it to hold it in place and six lengths of 1.3 cm gauge upright steel wire for reinforcement. "BRC," a heavy gauge welded steel mesh with a diameter of 5.4 millimeters, is recommended for extra strength (Lee et al., 1987). In all designs reviewed, the reinforcing mesh is overlapped and extends from the base into the wall and from the wall into the roof.

Although there is no general consensus regarding the ratio of sand to cement, generally, the sand/cement ratio for ferrocement is two to one (Desa, 1981; Pacey, 1986; Robinson, no date; Skoda & Reynolds, 1993) while ratios of one and one-half to one (Lee et al., 1987) have been used successfully.

Walls are generally formed first by applying the cement mixture to the mesh in two to three coats. Once the cement has cured, the forms can be removed and the interior of the tank finished by first applying a 50 millimeter layer of cement on the floor. When that layer has cured, two layers of cement are then applied to interior walls followed by a "thick cement slurry" to cover the walls and floor to make the tank water-tight (Pacey, 1986). Robinson (no date) recommends applying only one coat of mortar to the inside walls followed immediately by pouring a 60 millimeter thick floor. He suggests that a water-proofing agent may be added to this mortar mix. This same mortar mix is used to build-up a 78 millimeter contoured layer covering the wall floor joint (Robinson, no date). A sketch of a tank in progress, taken from the construction manual, is shown in Figure 7.

The roof form used in Robinson's design is made from seven wedge-shaped pieces of plywood forming a cone covering seven-eighths of the roof to allow for easy removal once the roof is in place. The form is supported by two-by-two pieces of lumber and a braced upright center post. The seven sections are coated with three coats of mortar mix. The form and bracing are removed and the final section of reinforcement wire is then cast while forming an overflow spout and a hatch and inlet opening (Robinson, no date).

In hot climates it is useful to paint a completed tank white to keep water cool and to reduce evaporation and thermal expansion and contraction that may produce cracks. Painting also improves the appearance of the completed tank (Figure 8).

Cracking, leading to leakage, can be also caused by a variety of factors such as improper curing (McPherson & Gould, 1987), shrinkage due to excess water (Ray, 1995) or an insufficient ratio of cement in the mix (Pacey, 1986). Additionally, major cracking and leakage may occur when, and if, untreated wire reinforcement corrodes. Corrosion, which may be caused by the presence of excess chloride ions in the

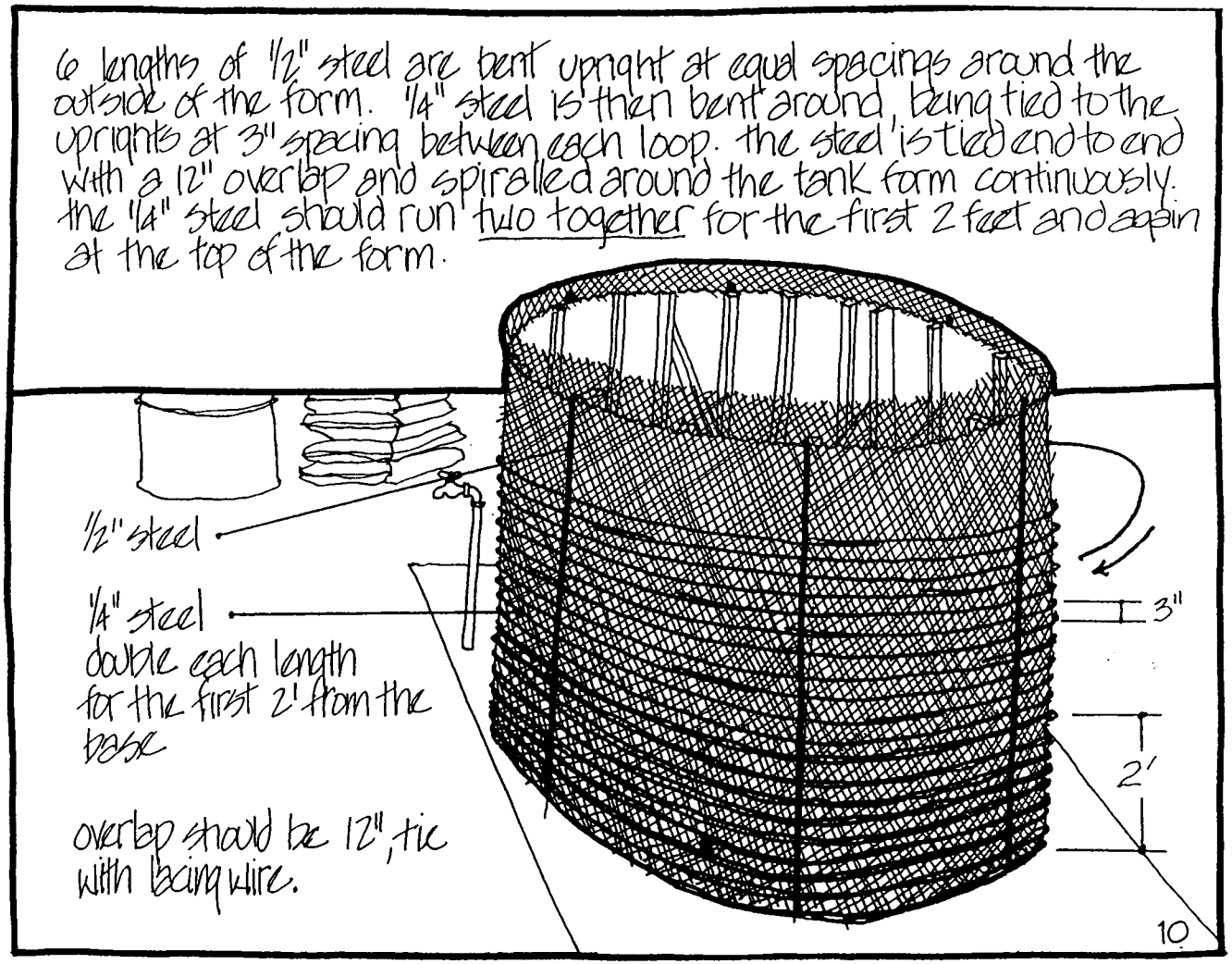


Figure 7. SVGCC/CCC ferrocement water tank under construction. Copyright ® Christian Action for Development in the Caribbean CADEC/CCC. All Rights reserved. Used by Permission (Robinson, no date).

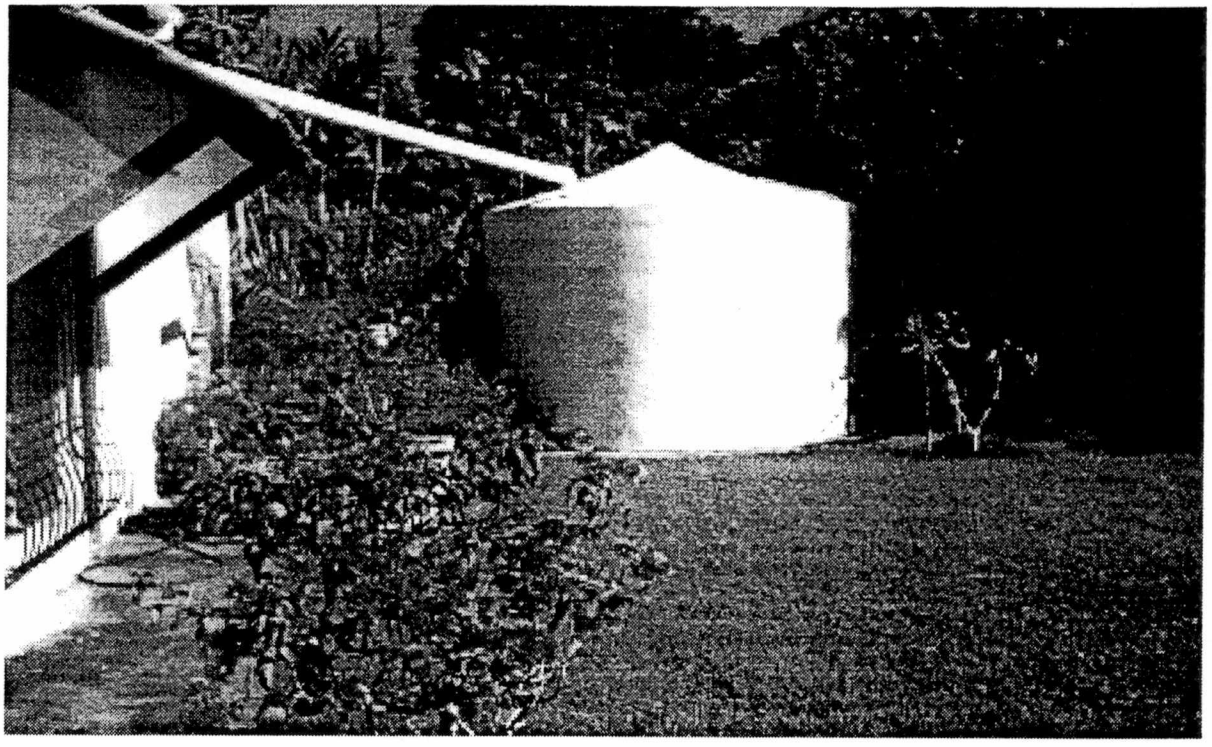


Figure 8. Painted ferrocement water tank in Bridgetown, Barbados.

mortar mix, will cause the reinforcing wire and rods to expand within the mortar (Ray, 1995). Beach sand, with a high salt content, may be all that is available for use on small islands and its use may result in excess cracking. Additionally, where fresh water is in short supply, as in the Grenadines during the dry season, tank builders may rely on brackish or sea water for the cement mix, accelerating the corrosion process. The use of galvanized reinforcing materials could reduce or eliminate corrosion.

The expected life of ferrocement has not been addressed in the literature, probably due to the range of construction techniques, quality of materials used and the attention given to details. A significant number of the ferrocement tanks built more than ten years ago through the SVGCC/CCC Project are still in use and many are functioning very well.

CHAPTER IV

RESEARCH METHODS

My research to evaluate the Low-Cost Ferrocement Water Tank Project was organized around four broad objectives. In order to develop a body of evidence for each of these objectives, I generated a set of discrete questions:

Objective #1: To evaluate water storage needs for private cisterns in light of present rainfall patterns in the Grenadines.

- What are the median annual and median monthly rainfall?
- What is the range of annual and monthly rainfall?
- What are the length and severity of the dry season that need to be considered?
- What are rainfall inputs and consumption outputs of water storage tanks on a month-to-month basis?

Objective #2: To determine the appropriateness of the ferrocement technology in terms of durability, cost and sizing.

- What is the condition of the tanks today?
- Are recipients performing regular tank maintenance and repairs?
- Are guttered roof areas sufficient in terms of tank size and demand?
- Is tank size sufficient in terms of household demand?
- Was this an economically appropriate means for providing water to people in the Grenadines?
- Recipients provided labor and some materials: Were tanks worth the effort?

Objective #3: To evaluate the effectiveness of the SVGCC/CCC Project in terms of whether the goals of the SVGCC/CCC were met:

- Has the technology been copied and/or improved upon, independent of the project, in the Grenadines?
- Has the water supply situation of poorer households in the St. Vincent Grenadines improved? [5]
- Have basic health practices and personal hygiene improved?
- To what extent have water storage capacity and water quality in the islands increased?
- Has the use of "brown water" (gray water) for irrigation and/or to water livestock evolved?[6]

---

[5] *Project Proposal*, no date (maybe 2/85), CCC. These were stated as objectives or goals in the request made to CIDA to fund the "Ferrocement Water Tank Construction Programme."

[6] *Christian Action*, Technology Transfer, 1982, Vol. 8, No. 5, August. Technology transfer is given as the direct objective of the endeavor to introduce ferrocement water tanks to the Grenadines. Indirect objectives established in the article address water quality and quantity, basic health and personal hygiene and developing the use of gray water.

- Has the status of recipients increased due to the ownership of a water tank?[7]

Objective #4: To evaluate the effectiveness of the SVGCC/CCC Project in terms of, the project's structure and administrative process:

- Was the process of choosing recipients fair and equitable?
- How was individual tank construction undertaken in terms of on-site monitoring and in-kind help?
- Was there any inventory or quality control?
- Were the project administrative process and structure efficient?

To get an overview of the administrative process and the project's structure, I met with S. Conrad Mason, in Barbados; with Carlton Williams of the St. Vincent and the Grenadines Christian Council (SVGCC) in St. Vincent; and with former members of island oversight committees, tank contractors, government officials and project participants in the Grenadines. I also reviewed project documents obtained from the CCC and the SVGCC.

Taking into account the storage capacity based on the current water holding ability of the ferrocement tanks built in this project, I calculated the water storage capacity they added to the St. Vincent Grenadines. Tank owners, government officials, contractors and other local people provided information regarding the replication of the tanks by others. Inspection of replicated tanks and informal conversations with their owners and contractors revealed modifications made to the original CCC design. Meetings with ferrocement tank owners provided insight into effects of the tanks on the quality of life, basic health practices and personal hygiene and on the adoption of gray water use, if any.

Meetings with tank owners and contractors and an inspection of 36 project tanks helped me assess the appropriateness of the ferrocement technology for the region. I utilized a questionnaire/checklist, where appropriate, during visits to project participants and I documented the current and past physical conditions of system components and the extent of needed and completed tank repairs. I determined the sufficiency of water supply for households I visited by requesting information regarding the frequency with which they required supplemental water from other sources. Final cost per tank was calculated from figures contained in the project's final budget, included in the "Final Report" by the SVGCC.

Rainfall data were obtained from the GSVG Central Water and Sewer Authority (CWSA), the Senior Airport Officer at the Mitchell Airport, Bequia, and a private citizen in Union who collects data for personal use. Anecdotal remarks made to me regarding rainfall amounts and distribution are utilized along with the actual data in discussions of current rainfall pattern trends.

---

[7] Mason, S. Conrad, Regional Programme Co-ordinator, CCC, author interview, Bridgetown, Barbados, May 31, 1994, and personal correspondence, February 7, 1995. Mr. Mason hopes that persons who received tanks have been elevated in their status in the community by virtue of ownership of a cistern because they now have a commodity that may be needed by and shared with their neighbors.

In order to study the effects that roof size, rainfall and consumption rates have on the sufficiency of the water supplied by the SVGCC/CCC ferrocement water tanks, I have set up a tank water balance. This idea came from a comment by Perrens (1982) who mentions the use of a water balance for sizing roof rainwater harvesting systems. The tank water balance used here is based on the concept of a hydrological water balance, which illustrates, on a monthly incremental time basis over an extended period, the water going into the tank, the water taken out and the water remaining in the tank. I have calculated 31 separate tank water balances to demonstrate the effect of monthly rainfall, roof size and consumption on sufficiency of water supplied by the 13,344 liter ferrocement water tanks. I set six scenarios by varying the roof and household sizes. Tank water balances using median and minimum rainfall data were calculated for the following scenarios:

- Four and seven-person households with a 25 square meter contributing roof area (cra)
- Four, seven and 10-person households with a 45 square meter cra
- One-person household with 25 square meter cra (minimal rain year only)

The tank water balance gives monthly water yields (the amount of water expected to be collected from the roof) as a function of roof catchment size and monthly consumption levels based on household size. Consumption levels may not always be directly proportional to household size primarily because cooking water does not increase incrementally. However, for simplicity, I have chosen to use a number that is incremental with household size.

The first step in the water balance is to calculate monthly yield as a function of catchment area and rainfall. A formula given by Pacey (1986) uses a standard runoff coefficient of 0.8 for metal roofs to determine this amount:

Yield (liters)=[(0.08)*(millimeters of rainfall)]*(square meters of cra).

The most frequently observed roof dimensions ranged from 20 to 29 and 40 to 49 square meters. Considering this frequency, I have used the mid-range of each group, 25 and 45 square meters, for roof sizes in my calculations.

The choice of rainfall data for each water balance involved several considerations. I had three sets of rainfall data (government data for Bequia and Union and independent data for Union) sufficiently large to perform statistical evaluations determining annual minima and medians. I chose the year with minimum rainfall from each data set for a worst case set of evaluations, and I used the year closest to the calculated median as a typical case.

Rainfall patterns in the Grenadines are seasonal and do not adhere to calendar years, so the several months preceding the year being evaluated will have a direct effect on the water supply making it necessary to start water balance calculations in the preceding year. I chose to start each water balance when the tank could be presumed to be empty. I assume this will occur at the start of the rainy season or, more specifically, in the first month with more than 100 millimeters of rain following a series of months in

which recorded monthly rainfall was less than 100 millimeters.[8] Additionally, where possible, a series of years with similar annual rainfall was included in a tank water balance that concluded with the statistical minimum or median year. I deviated slightly from my system when calculating the water balance for a representative median rainfall year for Bequia. The year 1968, with 1,466 millimeters of rain, comes closest to the median annual rainfall of 1,444 millimeters. But there are no rainfall data for the preceding year, so I chose to use 1977 with rainfall of 1,422 millimeters because I also have data for the previous year.

The next step in the tank water balance is calculating the output, the amount of water drawn from the tank for consumption. The rate of household water consumption determines how long a specific amount of water will last. It is a function of household size, and the uses and availability of water. When calculating system size, consumption estimates of three to ten liters per person per day have been used (Fuaud, 1984; Doelhomid, 1982; Yoganarasimhan, 1987). At this level, consumption would be restricted to drinking, cooking and minimal personal hygiene. My observations of water use in the Grenadines during the rainy season confirmed what has been noted by Pacey (1986) and others (Piggott et al. 1982; Pompe, 1982), that when water is abundant it may also be used for dishwashing, laundry and bathing. During my visit, people used their ferrocement tank water to wash laundry out-of-doors in 23-liter plastic buckets. Since these buckets are not filled to capacity I estimate that approximately 45 liters of water are used to wash and rinse one load of laundry per week for each person. These buckets are also used for bathing. I assume that, when tank water is sufficient, householders will bathe at home three times a week using two buckets or 45 liters of water and they will also bathe in the sea three times per week rinsing off with cistern water at their home using 23 liters. Dishes are washed in small, plastic or metal dishpans that hold about five liters of water. Assuming that dishes are washed once a day per person using two pans of water (one to wash, one to rinse) this adds 10 liters per day to the consumption. I have also assumed that household water consumption for drinking and cooking is ten liters per person per day. This gives a total of 389 liters of water used per person each week, 56 liters per day.

As the storage level drops, people tend to ration their water and find alternate sources for non-essential uses (Perrens, 1982; Piggott, et al., 1982; Pompe, 1982; Pacey, 1986). For my calculations, I vary the consumption rate according to the availability of water. In reality, tanks fill and empty through the month depending upon the rainfall patterns. Since sufficient daily rainfall records are not available to conduct a more detailed analysis, I have assumed a tank water level change at the start of each month. When the tank at month's start is presumed to contain more than 4,000 liters (slightly less than one-third full), I have assumed the non-rationing consumption estimate of 56 liters per day for each household

[8] Falkland, 1991; months with rainfall amounts of 100 millimeters or less are considered dry in the Caribbean due to high evaporation rates.

member. When the tank is presumed to hold less than 4,000 liters at the start, I have used a consumption rate of 10 liters per person per day (rationing consumption).

Sample household sizes for these computations were based on the data I gathered during my interviews with tank owners. Four and 10-member households appeared most frequently (five times each) and seven was the median number of household occupants. I evaluated a one-person household only for the case with the least recorded annual rainfall and the smallest cra evaluated for this study. This household size was included in my sample because it occurred in my survey four times and because there is a void in my interview data regarding incidence of overflowing for this size household. Although only one of the four single-person households reported tank overflows, only one reported no overflowing. I hypothesized that a tank of this size with only one water user will overflow, even with minimal rainfall and roof catchment area, based on reported incidence of overflowing for small size households in the Grenadines and the minimal water use of a single person household.

Finally, the tank water balance adds the roof water yield to the amount of water that was in the tank at the start of the month to calculate the amount of water available for use that month. The month's consumption is deducted from the available water and the remaining water carried forward for use in the following month (carryover). In some cases all the water will be consumed in one month and there will be no water to carry over. When there is not sufficient water to supply demand from the combined sources of yield and the previous month's carryover, and householders must collect water from another source, a deficit is indicated. At other times the tank may overflow because the carryover from the previous month plus the present month's yield exceeds what is consumed. I have included two water balance tables for Union in Appendix C.

Reliability, the ratio of months without a water deficit to the total number of months evaluated, can be calculated either by utilizing consumption based on rationing year-round (Pacey, 1986) or non-rationing year-round (Perrens, 1982). I evaluated system reliability based on the same scheme used in the water balance monthly consumption using a mix of and non-rationing that was dependent on available supply because I believe it more closely mirrors reality than constraining the usage to either rationing or non-rationing year round.

To evaluate roof catchment area requirements for individual household sizes I used the following equation:

required cra (sq. meters) per household = consumption (liters)/rainfall (millimeters).

I set up 10 separate scenarios. The household sizes and rationing consumption rates match those used in the previous tank water balance calculations. I used minimum rainfall data from the three rainfall data bases, but as a suggested design strategy to give insurance in severe situations (Doelhomid, 1987) and to size the system relative to the incidence of drought (UN, DTCD, 1987), calculated rainfall amounts as 85% of dry year values. Each required cra is derived by using an overlapping series of three consecutive months

following a design suggestion of Yoganarasimhan (1987). For example, if the first series of months is January, February, March. The second series would be February, March, April. Only the first five months of the year, generally the latter of the dry season, were used in this evaluation.

Questions I posed to evaluate the effectiveness of the SVGCC/CCC Project and the availability of potable water in the St. Vincent Grenadines are answered in the next section of this document. My evaluation of those results is given in Chapter VI.

CHAPTER V
RESULTS

In July, 1995, I spent five days in Kingstown, St. Vincent, speaking with SVGCC members and reviewing project paperwork, followed by a 23 day visit to Bequia, Canouan, Mayreau and Union islands of the St. Vincent Grenadines. This trip enabled me to acquire a much better understanding of how the project had been implemented and to see 36 of the 51 ferrocement tanks built during the SVGCC/CCC Project. Additionally, I collected rainfall data, observed storms and spoke with islanders regarding rainfall patterns. This background information helped me to answer questions set forth in my objectives.

Rainfall

Rainfall in the Grenadines fluctuates from season to season, year to year, island to island and even within an island. Most storms I experienced during the summer of 1995 were short duration events with intense precipitation. Four of six daytime storms were less than ten minutes long with four or fewer millimeters of rain each, and two lasted several hours. I did not record the length of seven storms that occurred during the night.

Rainfall Statistics

In order to evaluate water storage needs in light of rainfall patterns, it is first necessary to examine rainfall patterns in the Grenadines. Monthly and annual rainfall data for Bequia, Union and Canouan are given in Appendix B, which also includes data collected by the author during the summer of 1995 and recent data from the J. F. Mitchell Airport in Bequia (GSVG, Civil Aviation Dept., 1995). Rainfall records for Canouan are limited (only two full years are available) and there are none for Mayreau. Two sources provided rainfall data for Union island. Each set covers a different time period, but with some overlap between the two. Union data reported by the GSVG, Central Water and Sewer Authority show higher annual rainfall (956 to 2,867 millimeters) than are reported by Wall (685 to 1,259 millimeters) while data reported by Wall are closer to estimates given for the Grenadines by the Caribbean Conservation Association (1991) of between 762 to 1,360 millimeters of annual rainfall. Additionally, rain amounts from overlapping records indicated that Wall's data are generally higher than data of the GSVG. Since rainfall can vary by location within a relatively small geographic range, this may explain the difference in the two sets of data. The range, mean and median for Bequia and Union are tabulated in Appendix B and also presented in graphic form in Figures 9, 10 and 11. Canouan rainfall data are insufficient for this type of analysis. Any assessment of the rainfall pattern in the Grenadines is constrained by the limited rainfall data.

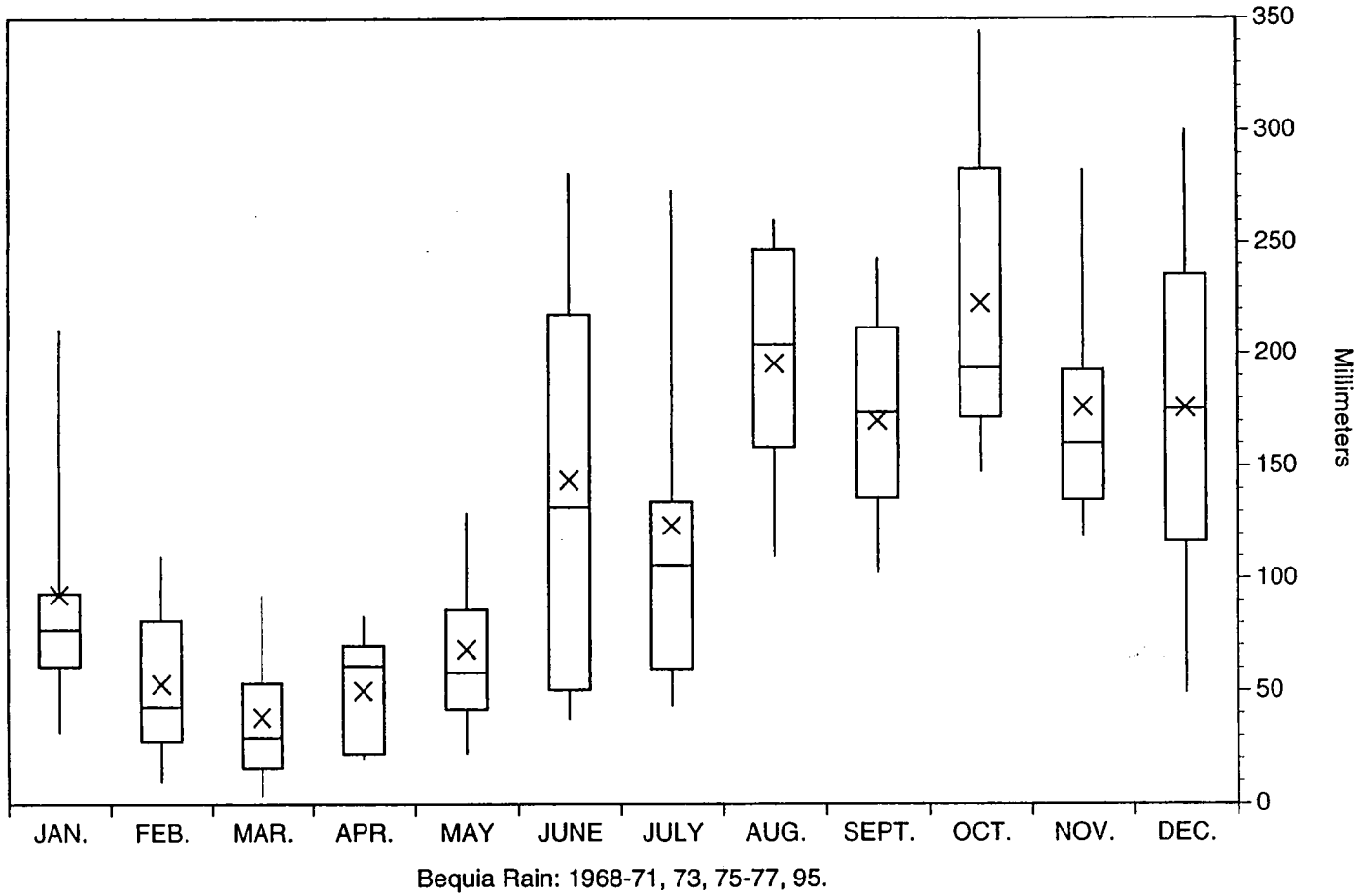


Figure 9. Graph depicting monthly rainfall statistical data derived from GSVG, CWSA data for Bequia. X marks median, - marks mean; 85% of months fall within range designated by elongated boxes and extremes are indicated by extensions.

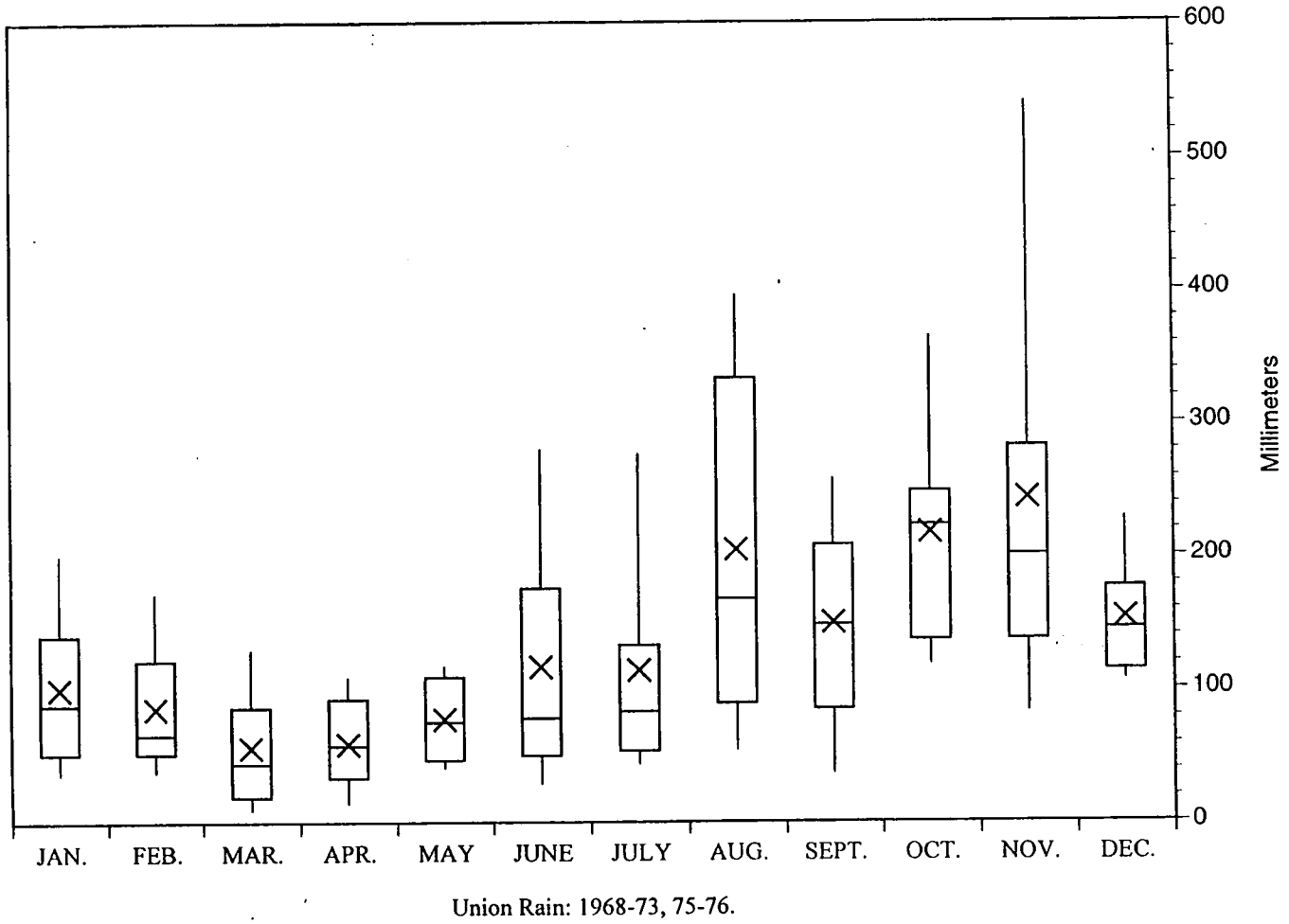


Figure 10. Graph depicting monthly rainfall statistical data derived from GSVG, CWSA data for Union. X marks median, - marks mean, 85% of months fall within range designated by elongated boxes and extremes are indicated by extensions.

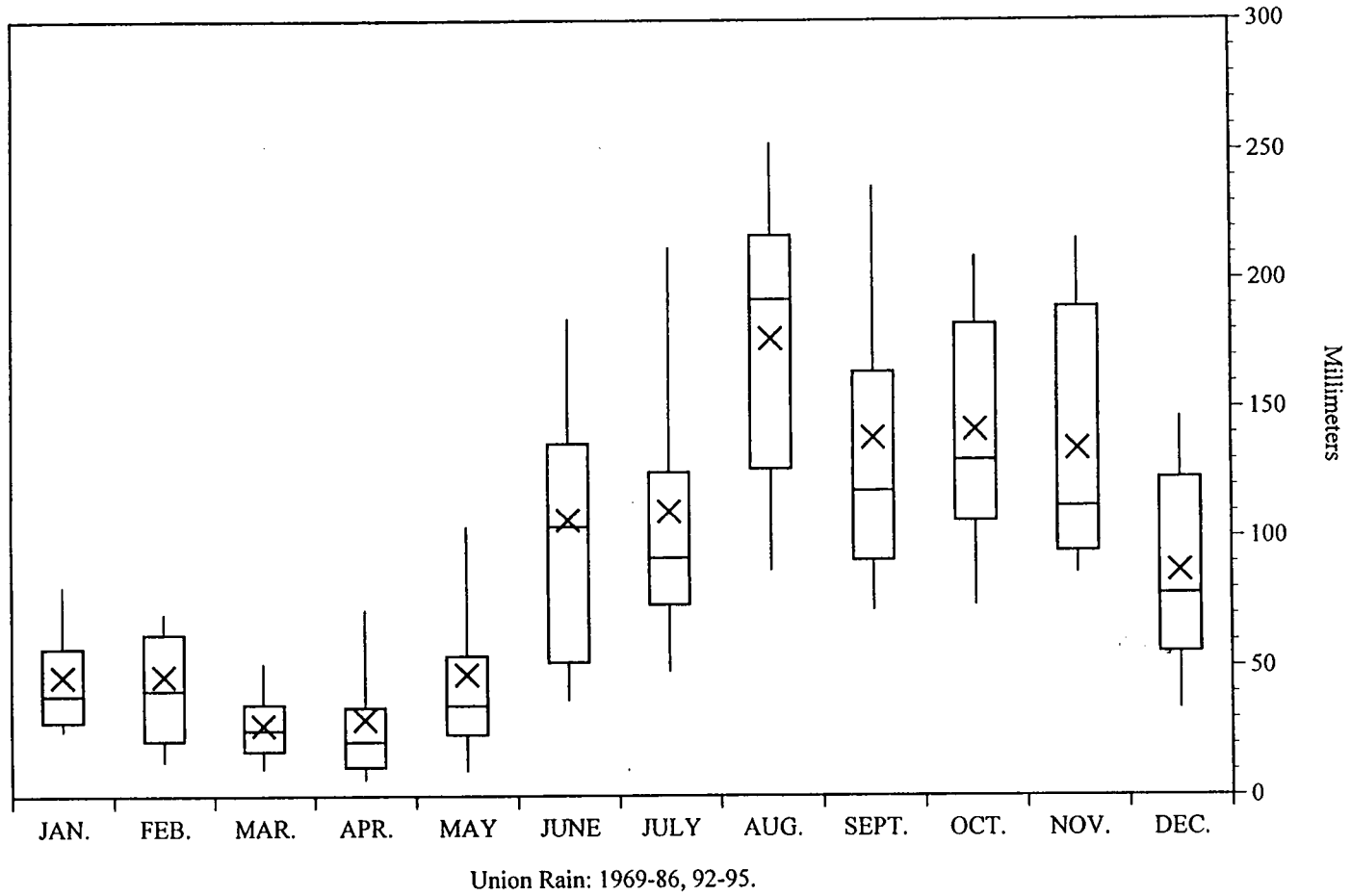


Figure 11. Graph depicting monthly rainfall statistical data derived from Wall data for Union. X marks median, - marks mean, 85% of months fall within range designated by elongated boxes and extremes are indicated by extensions.

Dry Seasons

The rainfall pattern throughout the Grenadines has defined annual wet and dry seasons, and there is some evidence that this pattern may be shifting somewhat with the dry season lengthening. This apparent shift can be seen in the historical data I collected and it also was related to me by people living in the Grenadines.

I had a conversation with Texas expatriate, John Caldwell, who has lived in the Grenadines for 29 years. He was one of several people to tell me that "years ago" the rainy season started in April (Caldwell, 1995). However, rainfall data do not substantiate his statement, so this may be an example of flawed perceptions. For instance, I note from available data for non-consecutive years that April rainfall in Bequia has never exceeded 100 millimeters in the nine years of record since 1969, that Union government data indicate rainfall has exceeded 100 millimeters only five out of 13 Aprils of record since 1968, and that Union independent data indicate April rainfall to have barely exceeded 100 millimeters only twice in the 20 years of record since 1969. However, the same data sources for the month of June, considered by researchers, government agencies and NGO's to be the start of the rainy season, indicate that rainfall exceeded 100 millimeters six times in nine years for Bequia; seven out of 13 in Union (government data) and only 11 of 21 in Union (independent records). Current records indicate that June is much rainier than April or May in the St. Vincent Grenadines, but there is still uncertainty about when the rainy season starts. Ongoing data collection may resolve this debate with a clearer delineation of the dry season in the Grenadines.

Regardless of when the dry season ends and rainy season starts, available records show that dry seasons in the Grenadines can be quite severe. Only 287 millimeters of rain were recorded in Bequia for January through July 1975. No records are available for the preceding months, which are also normally part of the dry season. Inclusion of those months would show even greater severity of that dry period. Records for Union (Wall, no date) indicate dry seasons that were more severe and of a longer duration than those in

Bequia. For instance, Union received only 238 millimeters of rain from December 1971 through June 1972 and 325 millimeters of rain from December 1974 through July 1975. Additionally, records indicate that dry periods of seven months duration are not unusual and that some have lasted 21 months. Separate incidents of extended dry periods (more than six consecutive months with less than 100 millimeters of rain reported) as depicted by available data for Bequia and Union occurred at the following frequencies: one each of 21 and 10 months in length, two of eight months, and six of seven months in length. The occurrence of extended dry periods underscores the need for adequately sized rainwater storage systems in the Grenadines.

System Condition and Function

Tanks

I was able to inspect 36 of the 51 ferrocement tanks. The conditions of the tanks I visited ranged from very good to non-functioning and are charted, in detail in the Survey Results, Appendix D. One of the tanks, on Canouan, has leaked severely from the base since the first rain following its construction and no longer holds water. I saw 15 with major leaks[9] while 18 have major cracks, wider than five millimeters. Four of the owners of tanks with major cracks did not report leakage. These were cracks along the seam between the top and wall of the tank. It is possible that if and when these tanks fill, water will flow out the overflow and any water leaking from the seam may be negligible and not reported to me as leaks. A total of 28 tanks inspected during my visit were leaking to some extent while eight had no leaks. Three of the eight with no leaks had never leaked and four had been successfully repaired (one requires yearly patching). Repairs of leaks had been unsuccessful on four tanks. I noticed a hard whitish substance that had filled in cracks along the walls of the water tanks, called "puddle" by the Grenadinians, which, as a Mayreau resident explained, works its way into small cracks to seal them as they develop. Puddle was evident in most (30) of the tanks that were inspected.

Eleven of the major cracks reported occurred along the seam connecting the tank top with the tank walls, and often, rusted reinforcing wire was exposed along this seam (Figure 12). One woman reported that the top/wall seam on her tank started to deteriorate about one month after her tank was constructed. One tank had several deep, narrow holes about 0.64 to 1.3 centimeters deep and 2 centimeters in diameter in the walls. At least one of the holes was leaking at the time I saw the tank.

Hatch covers that I reported on were in various states of condition. Six fit tightly and 12 were ill fitting for the following reasons: major or minor cracks between the frame and the cover, the hatch opening left ajar to allow for the down spout entry when none was provided in the tank construction or the hatch cover replaced by make-shift covers fabricated from corrugated metal (Figure 13), thin plywood or an array of boards placed over the opening. Additionally, some hatch covers were missing. One person reported that none had been provided by the contractor, so she had one built. Six of the inlet openings were sealed well around the down spout, five were poorly sealed and six had no specified inlet hole, requiring the use of the hatch opening for that purpose. Three tanks had been constructed without an overflow device.

Spigots on four of the 36 tanks were missing or broken and not functioning and two leaked severely. One person informed me that she had the spigot installed on her tank and two others had replaced their

---

[9] Major leak defined as: water seeping from a crack longer than one-half meter, area on tank wet to the touch and/or puddling around base of tank or householder complains that tank will not fill beyond the height of the leak. Minor leak: crack with water seeping out is less than one-half meter in length, no puddles, area not wet to the touch but may be damp and stained with water.



Figure 12. Ferrocement water tank with exposed reinforcing wire along top seam.

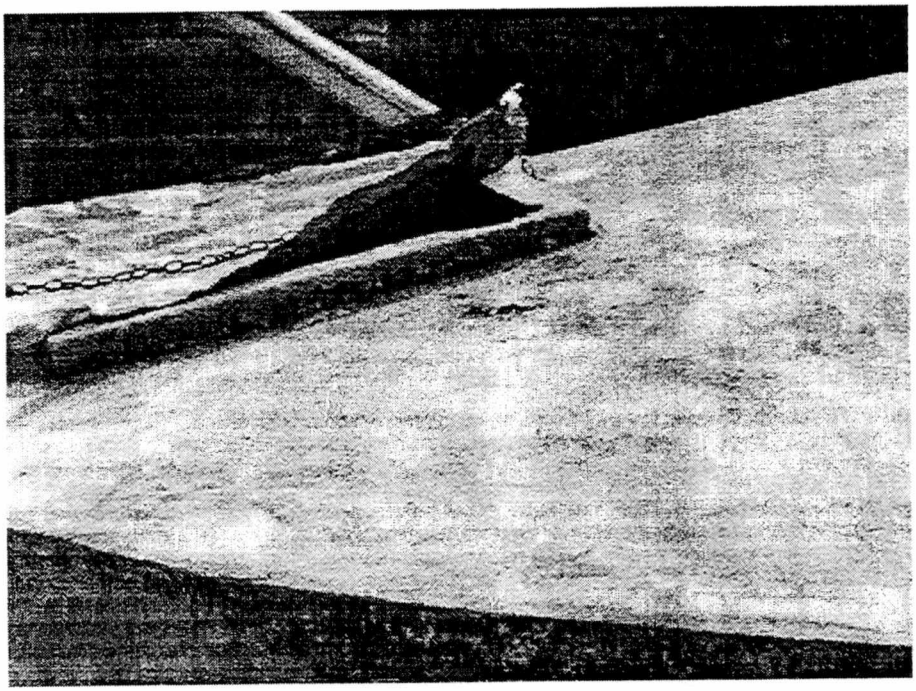


Figure 13. Makeshift hatch cover, a piece of corrugated metal laid over hatch opening.

spigots. Six reported that the tank had to be one-half full before they could draw water through the spigot. People bail water with buckets through the hatch opening when the spigot does not function.

Roofs and Gutters

Roofs and gutters affect roof collection system efficiency. Roof slope angles affect the rate at which water drains off the roof. Very steep angles are less efficient because the flow of water will be at a rate greater than the rate at which the gutters can collect it (Waller, 1982). Optimal roof shape and slope for rainfall catchments conflict with those for resisting hurricane damage. A steep sloped hip roof with little overhang is best at withstanding hurricane force winds. This would then require deep gutters to contain the runoff. Gable style roofs with low angles are the most prevalent in the Grenadines, which are less apt to endure hurricanes than islands to the north. Roof angles were generally between seven and 13 degrees; the smallest angle measured was three degrees and the largest was 45 degrees. A survey of roof styles and angles and gutter diameters in Bermuda could reveal how this problem was dealt with in a more hurricane prone region. Smooth, impervious roof surfaces are the most efficient because most water will run off into the gutters. All roofs in this study are covered with corrugated galvanized metal. The runoff coefficient (fraction of rain falling on the roof to water collected) for these roofs is 0.7-0.9 (Pacey, 1986). So, the angles and material of roofs in the Grenadines are ideal for collection of rainwater. It was impossible for me to examine all of the roofs. However, many of those I was able to observe were in good condition. Five were covered by more than 30% rust and were in poor condition and six had between 10 and 30% rust coverage but not enough to cause leaks or reduce the amount of water collected. The 10 remaining roofs I was able to observe had less than 10% rust.

Overflowing gutters may be a problem in this project. All gutters appeared to be 10 millimeters in diameter. The two people with whom I discussed gutter capacity reported they had noticed their gutters overflowing during heavy rains. Mr. Simmons, the mason in Canouan, suggested that gutters need to be at least 13 millimeters in diameter to reduce this problem. Gutters and down spouts need to be well maintained and supported to avoid depressions and sags, which allow puddles to form and become mosquito breeding areas. The joints between sections of gutters and down spouts need to fit tightly to avoid leakage that would reduce the system efficiency (Pacey, 1986). Of the 25 gutters I observed, 18 were in good condition, well supported and with tight joints, and seven were sagging and/or had loose joints. Four down spouts I observed sagged severely, one was supported by rags.

Since trees in the Grenadines are generally not sufficiently tall to overhang house roofs, leaf litter that would contaminate the water seldom collects on roofs or in gutters. Only one roof observed for this study had a tree overhanging it and the tree had few branches. Atmospheric dust and bird dung appear to be the main potential sources of contamination.

Sizing

Roofs

The size of the contributing roof area (cra) is one of the major determinants of the quantity of rainwater collected. The size of the catchment area (roof) was predetermined because the project provided cisterns for existing homes. However, guttering was not provided through the SVGCC/CCC Project. So, in some cases all slopes were not guttered and the total available roof area does not contribute to the water collected. The size of the cra observed in this study ranges between 20.9 and 134.5 square meters. Field measurements and interview responses regarding cra and family size relative to tank overflowing and sufficiency of supply are given in Table 1.

I was also interested in determining the roof area necessary to supply rationing consumption water to households in the Grenadines and results of my calculations are presented in Table 2. My calculations show the cra required to provide sufficient rationing water supply does increase with household size, as expected, and measured cra's are too small to meet rationing consumption requirements for ten of the large households (six or more members) whose roofs were measured, while one-person households are over-supplied with cra. Also, a one-person household requires only a fraction of the area of actual existing roofs using these calculations. Effect of cra to tank water level and sufficiency of supply, as calculated in tank water balances, is graphically illustrated in Figures 14, 15, 16 and 17, which compare two cra's for a four-person household under two rainfall regimes. Figures 14 and 15 use median and Figures 16 and 17 use minimal annual rainfall. Keeping in mind the constraint of having used monthly rather than daily rainfall data, the household with the larger cra generally has more water in storage at the start of the month.

Tank Size

A key point in evaluating the effectiveness of the ferrocement water tank project was learning whether the 13,344 liter capacity of the ferrocement tanks was sufficient to provide water supply through the dry season. The size of the water tank relative to the catchment area, rainfall and consumption rate determines whether it will provide water through dry seasons or overflow during wet seasons. When tanks are of sufficient size, all water collected may be stored for household use. If a tank is too small, water will overflow and be lost to the environment. Household size and consumption habits will affect the rate at which water is dispensed from the storage tank. Tank capacity, roof size and rainfall patterns determine the amount of water that is available. Despite a fairly high incidence of overflowing, those reporting sufficient supply were relatively few. Households reporting sufficient water supply were relatively small and larger households had to rely on an alternative water source to supplement their tank water.

The monthly increment tank water balance results (Table 3) demonstrate a somewhat different incidence of sufficiency and overflowing. Water supply was consistently sufficient in only one instance for

Table 1. Summary of field survey re: tank water supply sufficiency with measured roof areas.

REPORTED SUFFICIENCY OF TANK SUPPLY RELATIVE TO HOUSEHOLD SIZE AND ROOF AREA							
ISLAND HOUSEHOLD	TOTAL PEOPLE	ADULTS	ELDERLY*	ROOF: SQ. METERS	SUFFICIENT	OVERFLOW	SUPPLEMENTAL TANK
BEQUIA #1	1	1	1	na	yes	no	no
2	6	2	0	na	no	once	no
3	1	1	1	na	yes	na	no
4	10	6	1	68	no	no	no
5	2	2	1	26.8	yes	no	no
6	5	2	0	na	no	yes	no
7	3	2	1	73	yes	yes	no
CANUOAN #1	4	2	1	na	no	na	no
2	30	na	1	40.8	no	no	yes
3	10	10	na	20.8	no	no	no
4	6	3	1	33	no	na	no
5	2	1	1	22.9	no	no	no
6	8	4	0	47	no	yes	no
7	na	na	0	na	na	na	no
8	na	na	na	na	yes	no	yes
MAYREAU #1	11	6	1	na	na	na	yes
2	6	2	na	46.5	na	yes	yes
3	4	2	0	na	na	na	yes
4	9	5	0	72	no	once	no
5	4	na	0	na	no	yes	no
6	11	1	0	na	no	no	no
7	na	na	na	na	no	no	no
8	7	7	na	27.5	no	once	no
9	4	4	1	56.6	yes	yes	no
10	4	2	0	na	no	once	no
11	1	1	1	17.2	no	na	no
UNION #1	8	5	na	73.3	no	once	no
2	na	na	na	na	na	na	yes
3	na	rental	units	134.5	no	no	no
4	17	10	1	71.5	no	yes	no
5	1	1	1	60.9	yes	yes	no
6	10	8	na	103	no	yes	no
7	10	6	na	50.6	no	no	no
8	na	na	na	na	no	na	yes
9	7	2	0	na	no	na	no
10	na	na	1	45.3	no	no	no

* Elderly appeared to be 65 years of age or more

Table 2. Summary of roof area required to provide 10 liters of water per day per person for each household size indicated during severe drought.

	CALCULATED MINIMUM ROOF AREA REQUIRED FOR FIRST FIVE MONTHS (85%) MINIMUM ANNUAL RAINFALL				
ISLAND	**DATA SOURCE**	**YEAR**	**HOUSEHOLD SIZE**	**LITERS/ DAY**	**ROOF AREA SQ. METERS**
BEQUIA	GSVG	1973	4	40	38.63
			7	70	59.66
			10	100	85.23
UNION	GSVG	1981	4	40	58.51
			7	70	102.38
			10	100	146.26
UNION	WALL	1972	1	10	7.73
			4	40	38.31
			7	70	67.1
			10	100	95.78

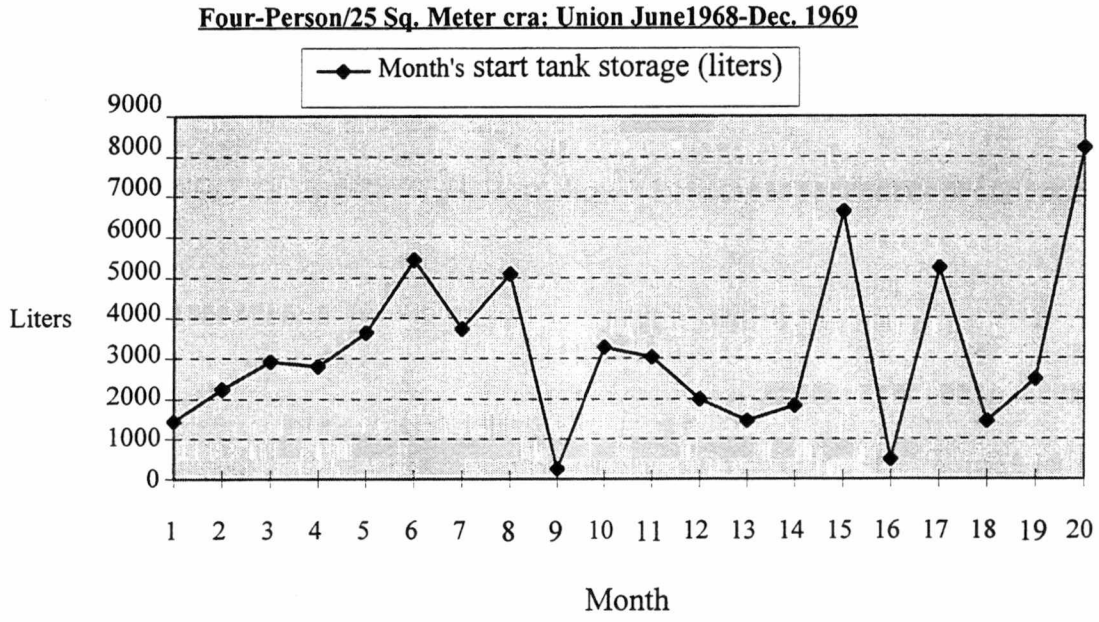


Figure 14. Graph from tank water balance using median rainfall data for Union (GSVG, CWSA, no date) and 25 square meter cra, depicting water level at month's start.

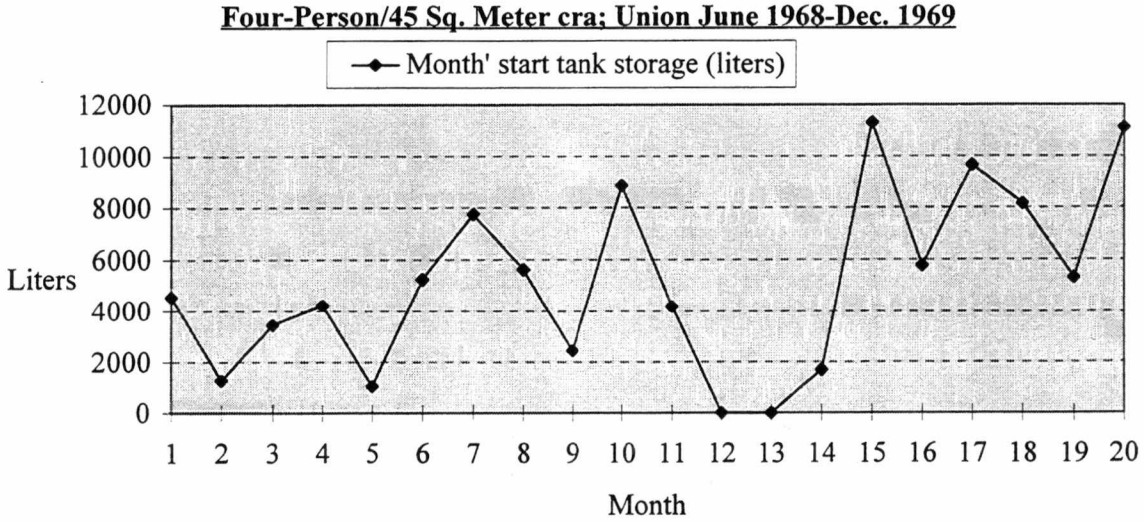


Figure 15. Graph from tank water balance using median rainfall data for Union (GSVG, CWSA, no date) and 45 square meter cra, depicting water level at month's start.

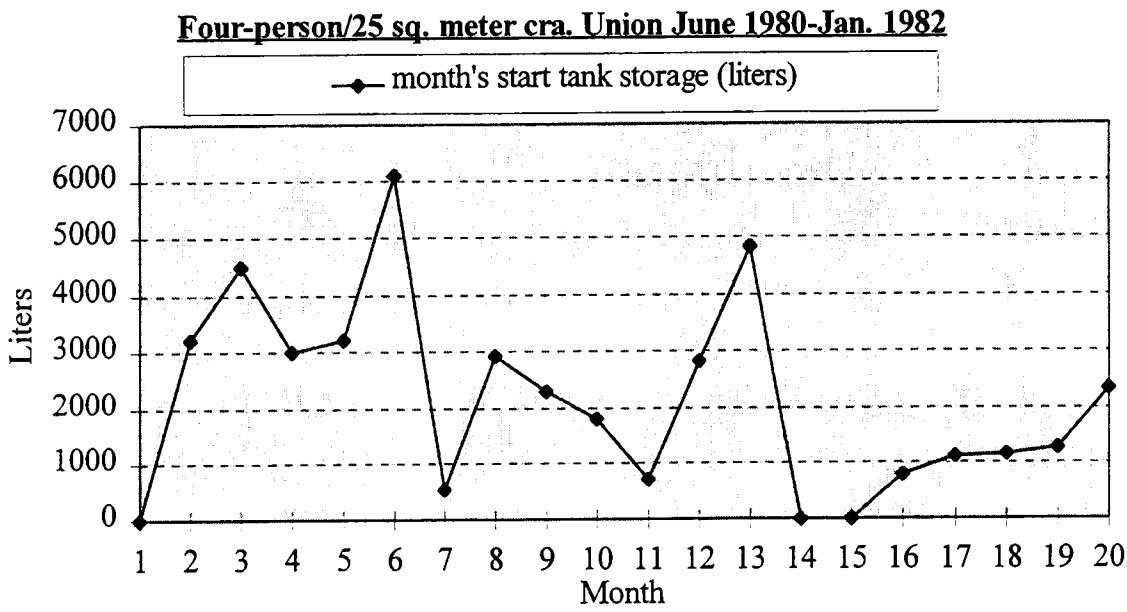


Figure 16. Graph from tank water balance using minimum rainfall data for Union (GSVG, CWSA, no date) and 25 square meter cra depicting water level at month's start.

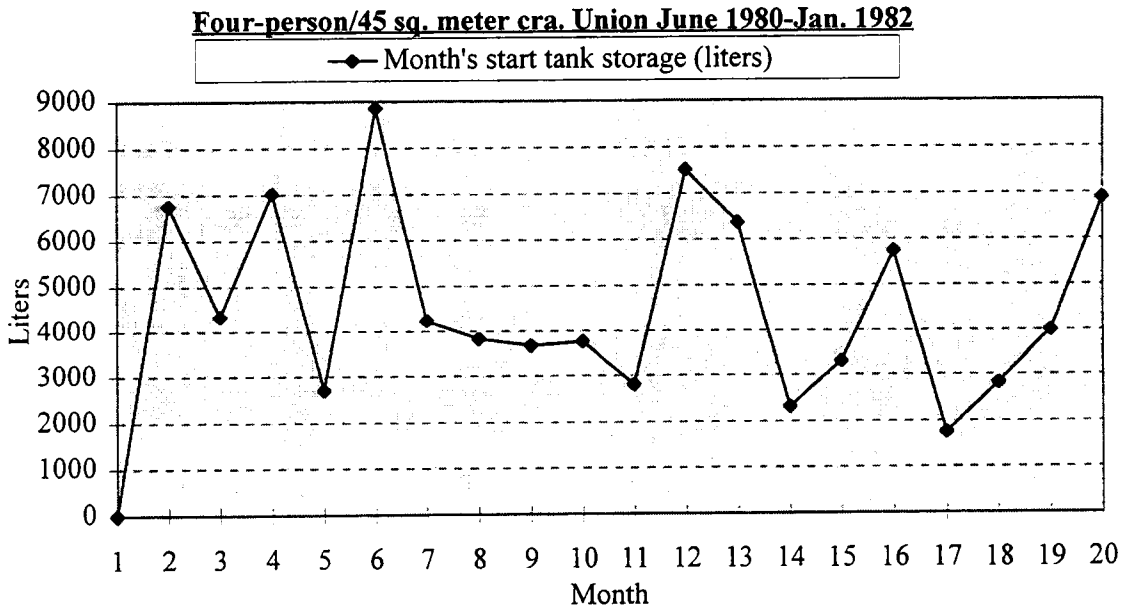


Figure 17. Graph from tank water balance using minimum rainfall data for Union (GSVG, CWSA, no date) and 45 square meter cra depicting water level at month's start.

Table 3. Monthly incidence of tank water supply deficit, overflowing and non-rationing derived from tank water balance computations.

	# months evaluated	# months deficit	# months overflow	# months non-rationing	reliability of the system to supply needed water
BEQUIA MED. YR.	19				
4 person/25 sq. meters		4	1	4	78.9%
4 person/45 sq. meters		2	2	13	89.5%
7 person/25 sq. meters		8	0	2	57.9%
7 person/45 sq. meters		6	0	6	68.4%
10 person/45 sq. meters		11	0	1	42.0%
BEQUIA MIN. YR.	12				
4 person/25 sq. meters		2	0	1	83.3%
4 person/45 sq. meters		1	0	3	91.7%
7 person/25 sq. meters		8	0	0	33.3%
7 person/45 sq. meters		3	0	1	75.0%
10 person/45 sq. meters		6	0	1	50.0%
UNION MED.YR. GOV'T DAT	22				
4 person/25 sq. meters		0	0	5	100.0%
4 person/45 sq. meters		2	0	13	90.9%
7 person/25 sq. meters		12	0	1	45.5%
7 person/45 sq. meters		8	0	8	61.9%
10 person/45 sq. meters		11	0	1	50.0%
UNION MIN. YR. GOV'T DAT	21				
4 person/25 sq. meters		2	0	3	90.5%
4 person/45 sq. meters		1	0	8	95.2%
7 person/25 sq. meters		7	0	1	66.7%
7 person/45 sq. meters		4	0	4	81.0%
10 person/45 sq. meters		11	0	4	47.6%
UNION MED. YR. IND. DATA	30				
4 person/25 sq. meters		9	0	6	70.0%
4 person/45 sq. meters		2	0	13	93.3%
7 person/25 sq. meters		16	0	2	46.7%
7 person/45 sq. meters		13	0	7	56.7%
10 person/45 sq. meters		14	0	5	53.3%
UNION MIN. YR. IND. DATA	70				
1 person/25 sq. meters		2	2	52	97.1%
4 person/25 sq. meters		20	0	6	71.4%
4 person/45 sq. meters		11	0	20	92.9%
7 person/25 sq. meters		48	0	2	31.4%
7 person/45 sq. meters		26	0	8	62.8%
10 person/45 sq. meters		47	0	6	32.9%

the periods evaluated using the tank water balance. Non-consecutive multiple incidences of overflowing occurred only for the four- person households with the larger roof, and consecutive overflowing events occurred for theone-person household evaluated and only following seven consecutive months receiving more than 100 millimeters of rain each. Table 3 also shows tank water supply to be insufficient (deficit) periodically in most situations.

Tank water balance computations using monthly rainfall data substantiate the effect the ratio of household size to cra has on the quantity of water supply. The highest ratio of monthly non-rationing to rationing consumption occurred for the smallest household evaluated, while the lowest ratio occurred for the largest household with the smallest cra evaluated during a year of minimum rainfall in Bequia. Also, monthly increment tank water balance computations demonstrate the effect that rationing and non-rationing consumption has on tank water level. Figure 18 graphically illustrates a tank water balance for a seven-person household in Bequia during a period with median rainfall. The month's start water level in the tank fluctuates widely, dropping in the month following a month of non-rationing consumption and rebounding following a non-rationing month. This effect was less pronounced for the four-person households and was nil for the one- person household examined.

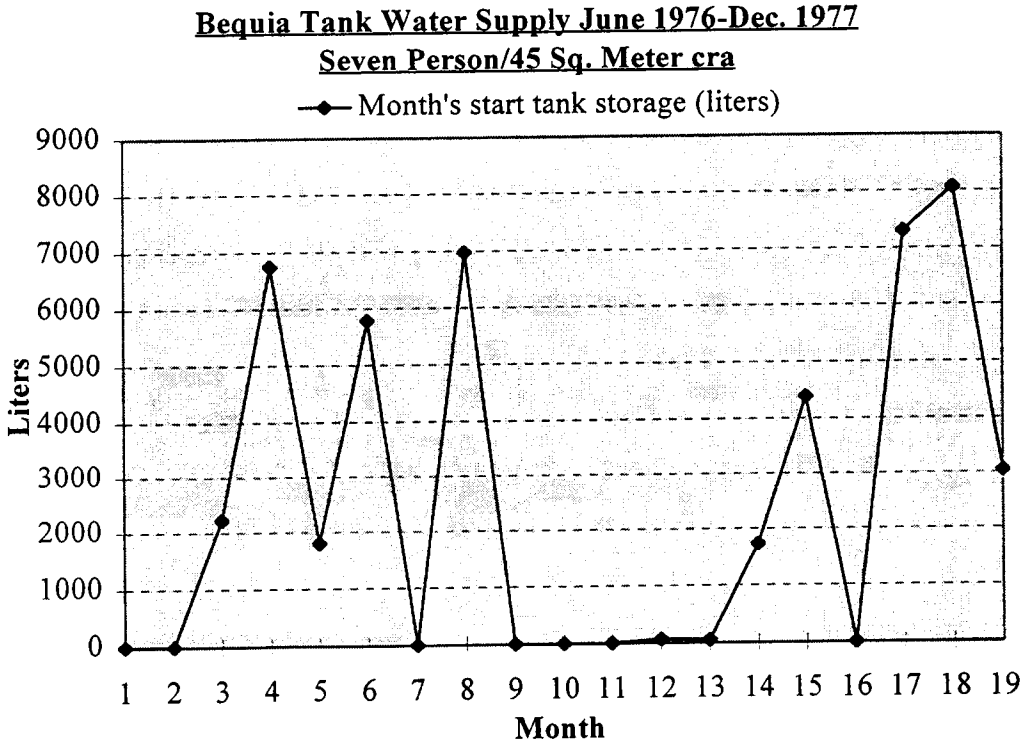


Figure 18. The effect of rationing on tank water supply. Rain data from GSVG, CWSA (no date).

Two sample tank water balances using GSVG, CWSA Union rainfall data presented in Appendix C show monthly rainfall and consumption from May 1980 through January 1982 and illustrate the effect of cra has on tank water sufficiency for a seven-person household. The year, 1981, had the least annual rainfall as reported by GSVG, CWSA. Total rainfall for the period shown was 2,122 millimeters. Water yield from the 45 square meter roof is estimated to be 76,392 liters compared to estimated yield from the 25 square meter roof of 42,440 liters. These tank water balances can be used to compare theand numbers of monthly water deficits occurring under the given circumstances, and the fluctuating tank supply.

Project Goals

Replication

Project designers introduced the ferrocement technology to the Grenadines in the hope that the technology would be accepted and more ferrocement tanks built. Ferrocement tanks have been constructed in the Grenadines independently of this project by the Government of St. Vincent and the Grenadines (GSVG). The GSVG modified the ferrocement construction design by increasing the overall dimensions of most tanks to a 4.27 meter diameter and a height of 2.13 meters, increasing the gauge of the reinforcing wire which increased tank strength and changing the outlet design from a U-shape to a shape with only one 45 degree bend (Ackie F., 1995; Simmons, 1995) allowing water to be drawn from the tank through the spigot when the water level in the tank reaches 10 millimeters. The water storage capacity of the government tanks is 30,501 liters compared to 13,344 liters of the CCC tanks. I saw several GSVG tanks while in the Grenadines and recorded information on two. They seemed prone to similar problems as those built under the SVGCC/CCC Project. Minor cracks were evident over the entire tank surface. Major cracking was primarily along the top and bottom wall seams. The fit and condition of hatch covers and inlet pipes varied. One recipient with whom I spoke had repaired leaks on her clone tank but the spigot pipe was broken and plugged. The other GSVG tank had been built as a demonstration at the home of a mason trained by the government in the ferrocement technology and was in excellent condition, as one might expect. There is uncertainty about the exact number of government tanks built in the Grenadines. Local committee members identified a total of 12 ferrocement water tanks in Bequia and I saw three government built ferrocement water tanks in Mayreau. The widow of the government trained mason in Union informed me that ten government tanks had been built there, and the mason in charge of the construction of CCC/SVGCC tanks in Union said 18 government tanks had been built in Union (Ackie F., 1995) and ten in Canouan. Stephens (1991) reported five had been built in Canouan. At least 24 to 32 GSVG ferrocement tanks were built in the St. Vincent Grenadines.

Additionally, a casual conversation with two young men in a leather shop in Ashton, Union Island, revealed that one or two individuals in Union had built ferrocement water tanks on their own because the design was economical to construct. Project participants who have replaced their ferrocement water tanks

or added supplementary tanks have not used the ferrocement design. Four of the six who have added second water tanks to supplement the water supplied by the SVGCC/CCC tanks have built large above ground concrete cisterns and use the water from the original tanks only for laundry. Two recipients have installed black plastic tanks. One told me that she was considering destroying her ferrocement water tank because it was in such poor condition due to the severe leaks. However, the construction of ferrocement tanks following the SVGCC/CCC Project is an indication that the technology is economically appropriate and has been accepted.

Basic Health Practices and Personal Hygiene

There was no educational component of the Low-Cost Ferrocement Water Tank Project in the St. Vincent Grenadines to instruct people in methods to improve basic health and personal hygiene practices. I was not able to observe personal hygiene and health practices of tank recipients. I would assume that these practices may have improved, to a limited extent, due to the improved convenience of the water provided by a household water tank.

Water Quantity

The water storage capacity of the St. Vincent Grenadines has increased by the number of liters of usable storage that was provided by this project: 13,344 liters for each properly functioning water tank or 680,544 liters if all 51 retained full storage capacity. Of the 36 SVGCC/CCC ferrocement tanks observed, 13 have minor leaks and 15 have major leaks. By deducting the 15 tanks with severe leaks and assuming that 36 tanks are capable of holding their full capacity, the increase in water storage is 480,384 liters. Eight of the 13 with severe leaks come close to filling with water. Three fill only to about half, two do not reach the half-full point and one no longer holds water. To estimate storage capacity of the remaining 15, I assumed water at 75%, 50%, 35% and 0% of capacity, respectively, for tanks in each set. This adds 109,421 liters of water storage. Thus, I estimate the current total water storage capacity increase in the St. Vincent Grenadines provided by the CCC/SVGCC ferrocement water tank project to be 589,805 liters.

Water Quality

I assume that the quality of rainwater in the St. Vincent Grenadines is good because there are no nearby facilities putting pollutants into the air that would contaminate the rain. Impurities may be picked up from the collection and storage components such as roofs, gutters and tanks. None of the recipients with whom I spoke divert the first runoff from the first storm following a dry spell (first flush). Five of the 22 systems that I checked for screening of the inlet water had screens in place. The strainer was generally a piece of metal mosquito screening attached on the end of gutter or laid over the inlet hole. One woman informed me that she only strained the water coming off the roof during the first rain following the dry

season. Most people whom I met in the St. Vincent Grenadines do not treat the water supplied by household water tanks. The preferred method, by those who do treat the water, involves keeping small fish in the water tank to eat mosquito larvae. This method is recommended by the Central Water and Sewer Authority (Browne, 1995) and is pretty universal, regardless of the type of tank. At least 12 of the tanks I visited had fish and the owners of several others reported that they have kept fish in their tanks from time to time. Only one person reported that he had used chlorine occasionally to treat his household water. Another reported to me that she boils her water "sometimes." Even with this minimal level of water treatment, not one of the tanks' owners with whom I spoke reported any illness associated with drinking tank water. A representative from the government health department visits each island once a year and tests water from all household water tanks for mosquito larvae (Browne, 1995). It would seem that the ferrocement tank project has not changed the quality of household tank water. However, the supply of potable water has increased and the people may use tank water for non-potable purposes in instances where, in the past, they would have used water supplied by public brackish wells. Appendix D documents the maintenance schedules, water treatment strategies and other information noted about the tanks that I inspected.

Gray Water Use

I found no evidence, either in the project documents or from my interviews, that there had been any effort to promote the use of gray water for irrigation and/or to water livestock. Crop planting had been delayed until the rains started and livestock roamed freely during my stay at the start of the rainy season. Tank water was reserved for human consumption in all cases, whether it was supplied by the new ferrocement water tanks or by the more traditional square concrete block tanks or the newer black plastic containers.

Status of Recipients

I did not observe nor was I able to gain any direct or anecdotal evidence that would enable me to evaluate any change of the status of participants within the community due to ownership of a water tank. None of the recipients had had a household water tank prior to the SVGCC/CCC Project. Thus the construction of the ferrocement water tanks has improved the water supply situation for some of the poorer households in the St. Vincent Grenadines

Project Structure And Administrative Process

Recipient Selection

I received several unsolicited remarks regarding the process of choosing tank recipients. Some people, particularly in Union, where there had been no formal application process, felt that the basis of

recipient selection was along the lines of religious affiliation and familiarity with one or more of the committee members. With the exception of one or two of the recipients whom I met, all appeared to meet the economic need criteria of being among the poorest households in the four islands (CCC, no date).[10] It has been ten years since the implementation of the project, however, and individual economic situations could have changed in that time.

The concept in the original project proposal for giving consideration to constructing single tanks to be shared by two or more households appears to have been overlooked in the actual implementation. Except for one tank in a house yard with three separate homes, all of the tanks I saw were constructed for individual homes. I believe that the three-house case was coincidental and that the tank was built to benefit only one recipient. Tank sharing was not mentioned in any conversations that I had with recipients, former committee members or contractors.

On-Site Construction Process

In most instances, the water tank construction was cooperative as stated in the project design. In one particular instance, the tank recipient was an elderly woman with few apparent financial resources. She was unable to find volunteer help for her labor portion, and evidently, the oversight committee was unable to solicit in-kind help. This elderly woman paid EC$450 (US$170) for the labor and additional materials necessary to build her tank. Other similar situations may have occurred, but I am only aware of this one.

There does not seem to have been any requirement for quality control. Construction monitoring on-site by either project staff or committee members was not mentioned in any of the project documents that I reviewed nor by committee members or recipients with whom I spoke. In Bequia, two of the oversight committee members were responsible for verifying the construction of each tank (SVGCC, 1984). I have no information regarding tank construction verification in Canouan, Mayreau or Union. Two tanks built with a great deal of owner involvement were designed somewhat differently than what was specified. The first, built in Canouan, was 3.66 meters in diameter, rather than the specified 3.05 meters. In Mayreau, a tank was constructed with the hatch opening placed in the center of the top rather than along the sloped edge of the top. A portion of the tank construction cost was paid to the mason in advance of actual construction, at least in Canouan where the mason received partial payment of EC$299 (US$112) per tank in advance.[11] Recipients and participating contractors with whom I spoke reported that the masons were

---

[10] The CCC Proposal submitted to CIDA states that 50 of the poorest households will be selected for participation and that the beneficiaries will be "the neediest cases on an individual basis."

[11] A shipping receipt in a file at the SVGCC office in Kingstown, St. Vincent dated 11/15/85, which was a record of material and labor costs for tanks built in Canouan, indicated that masons received advance payment for tank construction.

not required to return to repair any problems. A list of specific problems and omissions that occurred at the time of or immediately following construction is given in the Survey Results (Appendix D).

In Bequia, a procedure for material inventory control was set requiring the mason or person transporting the materials locally to sign delivery lists of the materials being delivered to participating households. Additionally, a household member would then sign the list when the materials were delivered to the residence. The mason in Canouan informed me that supplies shipped from St. Vincent for tank construction were kept to the exact amount needed for the construction of the specified number of tanks (Simmons, 1995). The inevitable loss that occurs in transport from breakage and possibly pilfering (my idea) was not taken into account when materials were ordered and shipped. In the case of Canouan, the cement portion of the mix was short for some of the tanks built and there was not sufficient cement to construct all the tanks to specifications (Simmons, 1995). In Bequia, the original shipment of cement and reinforcing materials was not sufficient to complete the last tank so a second shipment was made (SVGCC a, no date).

Final Tank Construction Cost

The total final cost incurred through the grant awarded to the SVGCC/CCC was US$30,943.63, which included a small portion (US$232.62) for travel and miscellaneous expenses. This was US$5,778.94 less than what had been budgeted for the project. The final project per tank cost was US$602.17 (for 51 tanks), US$156.63 less than the projected cost of US$758.80. The value that the project developers placed on recipient-provided labor and materials had been US$205.99. This would bring the tank value to US$808.16. However, if participants counted their labor as free and the estimated US$74.91 for household supplied materials was correct, the cost for each tank would be US$677.08. The recipient who contributed US$170.00 to purchase material and labor raised the actual total cost of the tank to US$772.17. Actual final tank cost thus varies slightly depending on the ultimate cost of household supplied labor and materials.

A discussion of the above findings is contained in the following chapter with particular emphasis on project structure and effectiveness, the appropriateness of the ferrocement technology, rainfall and system sizing.

CHAPTER VI
DISCUSSION

In this chapter I discuss the results of my field research as they pertain to the appropriateness and sustainability of the SVGCC/CCC Project in the St. Vincent Grenadines.

Rainfall Patterns

The pattern and characteristics of rainfall in the Grenadines would account for the discrepancy between the numbers of tanks that reportedly overflowed and the lack of overflowing apparent in the water balance. Most rain events that I experienced were intense and of very short duration. Because rainfall tends to be concentrated in heavy storms over short periods, the tank could overflow early in the month and yet there could be a deficit later. In fact, water that overflows during these periods is included as being available for consumption in the tank water balance where monthly rainfall totals are used. In a more precise computation of a tank water balance using daily data, deficits (those times when tank water is insufficient to supply household demand and water must be acquired from another source) and overflows would occur at different intervals and perhaps more frequently. To be truly accurate, a tank water balance would need more precise information on household consumption and daily rainfall. This could be accomplished with ongoing monitoring of rainfall and water use patterns in the study area as suggested by Appan and Wing (1987) and by a study of water consumption habits. Daily rainfall data collection in Bequia by the Civil Aviation Department, at the J. F. Mitchell Airport began in April, 1995. Should a similar project be proposed for the St. Vincent Grenadines, it would be appropriate to evaluate the rainfall with these data once several years of record have been compiled.

System Condition And Function

Tanks

Contractor Attitude

The varied physical condition of the tanks that I saw may be attributed to one or more contributing factors. My observations and a remark made by a Union resident lead me to conclude that the tanks constructed when the homeowner, particularly if it was a man, worked closely with the mason, were more durable. Additionally, contractor attitudes are likely to have contributed to the level of attention paid to details. S. Conrad Mason (1995) explained that when completing a project for a poor household at a house in run-down condition, a contractor may not make an effort to do good quality work.

Contractor attitude may be improved by helping contractors take personal interest in the ferrocement tanks. This might be accomplished by getting contractors involved early-on in the process to help in the tank design or painting each tank with a design or color to identify the contractor who supervised its

construction. Additionally, acceptability and replication of the technology could increase by improving the aesthetics of the tank in this manner.

Materials

Improper materials or lack of sufficient materials would also affect tank quality. Reverend Andrew Hatch, formerly of the CCC (1995), suggested that the use of salt water in the mortar mix might cause cracking. This was confirmed by Carl Ray of American Limestone in Knoxville, Tennessee (1995). Salt induced corrosion and swelling of the corroded reinforcing wire will cause cracks and breaks in the cured cement. The small size of these islands would mean that salt spray from the ocean would often reach far inland and be deposited on the ground. So, sand mined either from the beach or from inland locations might contain salt. Although this problem may not be overcome on small islands due to the lack of salt-free materials, it can be lessened by using materials with the least salt and retarding the corrosive effect of the salt by using only galvanized reinforcement materials.

In Canouan, the shortage of cement resulted in a reduction of the cement to sand ratio, which would have affected the integrity of the cured cement and might have resulted in cracks (Simmons, 1995). This may have occurred throughout the four Grenadines. Given that severe leakage may result from an inadequate sand/cement mix (Falkland, 1991), it seems that this problem could be overcome with minor adjustments in the method of estimating needed materials. By factoring in extra cement to cover losses that could occur in transport and storage, sufficient cement could be made available for all tanks.

Some consideration must be given to earth tremors, frequent occurrences in the Caribbean, as factors that could cause cracking and subsequent leakage. However, based on evidence such as location of major cracks, reports of material shortages and remarks regarding quality of work, I believe the latter factors were more influential in causing tank cracks.

Components

The lack of critical tank components, such as inlet holes, overflow and hatch covers, could also have been caused by contractor attitude or a shortage of necessary parts. Without the inlet hole, householders are forced to leave the hatch cover ajar to accommodate the down spout. This increases the possibility of insects, small animals and debris entering the tank and contaminating the water. Concerning missing or inappropriate hatch covers, the originals may have been damaged due to frequent use for tank cleaning and water bailing. In one instance, the hatch cover may not have been built at the time the tank was constructed. The lack of an overflow outlet may add stress to the tank as the water rises above the wall/roof seam. But, water will eventually overflow through cracks or the inlet or hatch cover openings, whichever are lower. One woman explained that she had the spigot installed after the tank was constructed. However, she also had a rather elaborate locking box built around her spigot to deter water thieves. It could be that

she was referring to the box only when she related this information. Procedures for the inspection of completed systems could reduce the incidence of these problems. Even in Bequia, where a committee member was responsible for verifying tank completion, at least one tank was built without an inlet opening.

Spigot Design

The owners of the six tanks with spigots that only work when the tank is more than half full have to climb to the top of the tank and use a bucket to bail water. This was not a problem with all of the tanks built through the SVGCC/CCC Project and, according to one person, the problem does not occur in the government built tanks because of the change made to the piping configuration. The reason for this problem with water draw is not evident. As long as the water level is above the spigot, the water should flow regardless of the piping configuration (Harrison, 1995). However, this flaw is a serious inconvenience and could have been avoided with only modest effort.

Tank repairs

When discussing the need for tank repairs, two former committee members remarked that people's attitudes kept them from making the necessary repairs. It was the opinion of the former committee members that because tanks were "given" to the people, the recipients felt that the donor should be responsible for repairs. I found that many of the recipients were elderly and physically unable to make the needed repairs, but that many of the people who were capable had made repairs. I do not know the cost of repairs, but assume that most tank owners do not have the financial resources to pay others to make repairs. If women are the household members responsible for repairs, as is often the case in the St. Vincent Grenadines with so many women-headed households and with men away for long periods at sea, do they have the necessary skills and tools? Training in methods of repair and system maintenance, which is overlooked by most planners (Grover, 1982), may reduce the incidence of major leakage and missing or broken components. Well-maintained systems operate more efficiently and for a longer time than those that are not. The training of recipients is advocated by those who feel that maintenance of small water supply systems such as household roof catchment systems is best done by the householders (WHO, 1982; Schiller, 1982; Chauhan, 1983). This training can be given by the administrative organization in non-formal courses (Appan & Wing, 1987) or by a designated community technician trained by the administrative organization (Sornjitti, 1987). In either case, in light of the erratic schedules of system maintenance, I feel it would be very helpful to produce an owner's manual that outlines a maintenance schedule as suggested by Pacey (1986) and clearly demonstrates methods of simple repairs and maintenance. An alternative would be to assign repair and maintenance responsibility to community members (UN, DTCD, 1989a) or to existing community organizations (Pacey, 1977) who are trained by the administrative organization. This would be most helpful for those recipients who are physically unable to make their own repairs and do maintenance.

Organizations that might be interested in taking over such responsibilities may exist in the St. Vincent Grenadines. A member of the Bequia Rotary Club with whom I spoke expressed his concern about the need for tank repairs in Bequia and thought that it might be a project that the Rotary would take on (Belmar, 1995). There is a Preservation Society in Canouan and similar groups may be in existence in Union and Mayreau. Alternately, community groups could be developed specifically for this task.

In several instances, leakage and other problems started within a few months of tank completion. If contractors were held accountable for the quality of their work, some of these would have been fixed early on. This could be done by requiring masons to guarantee their work for a specified period of time, such as one year. Withholding payment until the tank is inspected by a project representative would aid in alleviating problems of quality and missing components. It may be that contractors in the Grenadines do not routinely return to a job once they feel it has been completed, but it seems to me that under externally funded projects this policy could be modified. Perhaps contractors perceived the allotted payment to be insufficient, as indicated by the fact that one mason refused to build the tanks for the price offered.

Reporting problems to the administrating agency could be arranged by building a communication loop into the project implementation scheme. It is the opinion of Grover (1982) that people in developing countries rarely complain about repair problems because systems are broken down so frequently. Even though most people were quite candid with me regarding problems they experienced with their tanks, this information had never been relayed to SVGCC or CCC. The administrative agencies remained, seemingly, unaware of these problems because there was no process built into the original project for feedback. Riney (1972) commented that these feedback methods must be developed and must become an essential part of the aid process so that problems can be addressed early on.

Another critical issue related to repairing the ferrocement water tanks is the need to keep them functioning to avoid the difficulty with their disposal, since lack of landfill space and increased generation of trash is a grave problem in the Grenadines and elsewhere in the Caribbean. If a non-functioning tank is broken-up, as one recipient is considering, the cement will not break-down in the way organic material does, and the rusting wire would be an eyesore with potentially dangerous sharp ends. On the other hand, if the non-functioning tank is left standing it will occupy usable space and also create an eyesore.

Guttering

Gutters and down spouts, integral system components, were not included in the design of the ferrocement water tanks nor was their cost included in the project budget. Pacey (1986) notes that this is often overlooked in rainwater harvesting projects. It may be that guttering is so simple compared to tank construction that it is taken for granted by project designers. Pacey (1986) also remarks that gutter installation may be such a formidable task that it discourages certain people from acquiring tanks at all. I noted that 11 of the roofs were only guttered on one slope. Although I did not report the number of roof

slopes that were guttered at two homes, I assume that because of the small roof dimensions, less than 30 square meters each, I had measured only the one side which contributed to the water tank. Guttering all roof slopes may not have provided the basic rationing water needs in every case because of limitations of existing roof sizes and the number of household water consumers, but it would have doubled the water supply, at least, for those cases. From my observations I assert that it is crucial that guttering of all sloped roof edges be included in projects that install household water tanks. This will insure the highest possible yields from the existing roofs on participants' homes. The only instance noted in the roof area calculations in which a small roof catchment would provide adequate water for drinking and cooking was for the one-person household.

I suspect that, because of their size, gutters connected to the ferrocement water tanks in the Grenadines are prone to overflow. I only inquired about overflowing of gutters in a few instances. Two people had noticed the gutters during heavy rains and both said that the gutters overflowed. The runoff coefficient used in the tank water balance makes some adjustment for overflowing; however, gutters may overflow in excess of this adjustment so that actual yield will be less than what is estimated in the tank water balance. A study to determine optimal gutter diameter as it relates to roof size, slope and rainfall would be warranted to aid in increasing roof catchment efficiency.

Sizing

Tanks and Roofs

The use of tank water for all household needs (non-rationing) has a dramatic effect on water availability for the larger households studied (seven and ten members). The graph shown in Figure 18 (page 78) depicts this effect. The water level in the tank fluctuates widely. Month to month tank water supply ranged from zero to 8,000 liters at month's start between June, 1976 and December, 1977. This effect was less pronounced for the four-person households and nil for the one-person household examined.

Tank water balances point out the strong relationship between roof and household size and the sufficiency or reliability of water supply. Generally, the highest reliability occurred in the calculations using four-person households and 45 square meter roofs. With the exception of only two cases, system reliability increased as the cra increased for like household sizes. The increased incidence of rationing increased the reliability in both cases (Table 3, page 76).

Interviews with tank owners were not extensive enough to compare with results of the tank water balances because inquiries were not made relative to water rationing. However, interviews indicate that water supply was sufficient for small households (two or fewer members), even with small cra.

The importance of adequate roof catchment areas is verified by the roof area calculations. These calculations reaffirm that it is critical that guttering of all sloped roof edges be included in projects that install household water tanks to maximize cra.

Economic Appropriateness

Comparing the cost of constructing the SVGCC/CCC ferrocement water tanks in the St. Vincent Grenadines to costs of ferrocement tanks built in other areas of the world during the same decade cannot be done because data are not available. I have final per tank cost from the project budget but actual figures for recipient contributions of materials and/or labor for only one recipient. Considering that the 1987 average annual income was US$1,000 (CCA, 1990) the per tank investment of US$75 to $170 was formidable for each recipient. Although owners of the tanks with severe leaks did not refer to the loss of their investment, it seems that it would have been a great financial loss to them.

The annual cost of water supplied by these tanks can be estimated by using the final expenses incurred through this grant and those incurred by the one reporting recipient. For the ten years that the tanks have been in use, water from each tank has cost US$60.21 per year from the project budget for the water delivered. Where the recipient contributed US$170, her additional cost has been US$17.00 per year. Assuming a 20 year tank life (Goh & Ramli, 1987) the above annual water cost would be halved. This seems to be a fair price for the convenience of having a supply of potable water close at hand and it is economical compared to other alternatives such as a new public catchment or desalination. Note that these figures do not take into account any maintenance or repair costs.

Housing Issues

Money may not have been well spent in building ferrocement water tanks in certain instances in which the need to improve basic housing may have been greater than the need for a water tank. The eight roofs that I saw that were more than 30% rusted may have gotten to that condition during the ten year interim between the project implementation and my visit. One particular house sticks out in my mind. It was occupied be an 82 year old woman and her 11 year old granddaughter. The roof leaked severely, the gutters sagged greatly and the foundation under her house was falling away. Only about one-third of the fieldstones supporting her home remained, and her water tank leaked so severely it held no water. Conversations with her and with her neighbor led me to believe that her housing had been in dire need of repair even before the tank was built for her. I may have misinterpreted these conversations and be incorrect in my inference, but the issue of inadequate roofs, like the issue of supplying guttering, was never addressed in the project proposal and was never mentioned as an issue by committee members who chose recipients. Pacey (1986) notes that most household rainwater system projects do not tackle major problems of repairs. He advises that, when such a project is focused on helping low-income groups, the bad state of their housing also needs to receive attention. Winarto (1987) echoes this opinion and lists the adequacy of existing roofs as one of two major roof harvesting system design criteria.

Project Goals

Replication

Transfer of the ferrocement technology and the promotion of its use to build low-cost water tank in the Grenadines was a major objective of the SVGCC/CCC Project. S. Conrad Mason (1995), expressed disappointment that the people used the more expensive concrete block method when they built tanks to supplement or replace their ferrocement water tanks. He is of the opinion that there may be a stigma connected to the round, not so expensive tanks and believes that Caribbean people want to have the more modern, more expensive things that they see the upper-class people have. This was somewhat substantiated by a comment I received from a Union woman, not connected with the project in any way, that the round tanks are "so old-fashioned." The physical appearance of all of the ferrocement tanks could have be improved by painting them. Reverend Andrew Hatch lives in an upper middle class neighborhood in Bridgetown Barbados. He has built two of the ferrocement water tanks, one at his own home and a second across the street at his rental property. Both have been painted white and are aesthetically pleasing (Figure 8, page 48).

Pacey (1986) attributes the relatively high rate of water tank replication some agencies experience to the comprehensiveness of their packages. Projects that are successful in promoting replication of water tanks assist with information, skills, and money. Additionally, they make provisions for follow-up and monitoring (Pacey, 1986). In the SVGCC/CCC Project, skills in the ferrocement technique for constructing water tanks were provided only to masons who participated in training. Pacey (1986) believes that the a simple construction manual like the one written by Robinson, and involvement of the commercial sector in projects, such as the masons in the Grenadines, aid in replication of the technology. The low level of replication might have increased had the information and skills in proper maintenance and repair techniques been also provided to recipients. A self-help ferrocement water tank project in West Java was preceded by a pilot project. From that experience, an instruction manual was produced for the final project that included all the learned lessons of the pilot project. The West Java project included a 12 day training course for all participants (Kerkvoorden, 1982). It may have been that people in the St. Vincent Grenadines did not readily replicate the design because of the problems that occurred with the original tanks or perhaps the ferrocement tanks were just too small to fulfill their current water needs. One person who was building a supplementary tank was planning to install plumbing in his home and needed the large capacity a concrete block tank would provide. Others may have chosen to construct the larger capacity tanks on the basis of household size.

Considering only the ease of construction and the relatively low cost of supplying potable water, the ferrocement technology is a good choice for building subsidized water tanks in the Grenadines and elsewhere in the Caribbean. The Government of St. Vincent and the Grenadines chose to use the ferrocement technology in a water tank project they administered following the SVGCC/CCC Project. At

least two people in the Grenadines chose to build ferrocement water tanks on their own. Project designers may have hoped for a higher number of independent replications in the Grenadines but there may be more independently built ferrocement that have not become apparent. Many people who are still without a home roof collection system and who lack the financial resources to construct any type of tank would be very satisfied with a subsidized ferrocement water tank. The several requests that I received from people to be put on the list to receive a ferrocement water tank affirm this.

Personal Hygiene and Basic Health Practices

Although there was no evidence in project documents that indicated a health and hygiene education component was included, such a component is not a need in the Grenadines where people are relatively well educated and very aware of basic personal hygiene and health practices. It may be that CCC assumed that the increase in the potable water supply for the participating households would automatically improve their ability to put these health and hygiene habits into practice.

Water Quantity

Despite the problems of tank leaks, the quantity of potable water in the St. Vincent Grenadines has increased as a result of the SVGCC/CCC Project. The calculated added storage of approximately 480,384 liters is greater than the storage of the new water catchment under construction in Bequia in 1995. It would be interesting to investigate what impact the increased water storage provided by the ferrocement tanks has had, if any, on the frequency of water shipments from St. Vincent. On the other hand, it is likely that the population increase over the past decade has offset or even increased water demand beyond the increase in supply.

Water Quality

Without monitoring water quality, it is impossible to discern whether the quality of water in the Grenadines has improved as a result of this project. Water quality improvement may have also been an assumption on the part of the CCC on the basis of the increase in supply of potable water. However, the lack of reported illness from those who drink the tank water suggest that tank water quality does not pose a problem in the Grenadines.

Gray Water Use

The little gray water use that I was able to observe during my visit seemed to have been a long-standing habit on the part of one person to use used water for ornamental plant watering and dishwashing. Water use in the Grenadines is of such low volume even during the rainy season that it does not seem that

there would be sufficient amounts of gray water to irrigate gardens or water livestock, particularly during the dry season when household use goes down and crop and livestock needs increase. As far as I could tell there was no effort made to make islanders more conscious of the possibilities of using gray water. However, it may not have been an appropriate objective because of an inadequate generation of gray water.

Status of Recipients

S. Conrad Mason of the CCC wondered whether ownership of a water tank had raised the status of the recipients within the community, in part, by virtue of their now having water to share with their neighbors (Mason, 1995). Most of the few people who had excess water did share it. Having a personal water supply in an area where this resource is often in very short supply could be empowering. Those recipients who share excess water with neighbors may receive additional respect, at least from those with whom they share. I became aware of only one woman whose water was coveted by a neighbor. Although she shared her excess, she had experienced a problem with a water thief. Ownership of a water tank has improved the lives of most of the recipients. I found that the majority of people were grateful to have participated in the project and were satisfied with the water from their new water tanks. Ownership of a water tank added convenience, even if for the short time when the tank supplies water, and ownership fosters independence. Having one's own water supply saves time and energy that would have been exerted traveling to the community catchment or stand pipe and alleviates the need to go to a neighbor for water.

Project Structure And Administrative Process

Recipient Selection

Recipient choice must have been difficult and it may be inevitable that those who were not fortunate to be chosen felt it was due to favoritism. The SVGCC/CCC Project was too small to assist all the households that were deserving. S. Conrad Mason (1985), after visiting the Grenadines when the project was being implemented, reported the need for at least 53 additional tanks to be built in Canouan, Mayreau and Union. Additionally, I have no reason to doubt that the three recipients who had the financial resources following the project to build large concrete cisterns at their homes had met the economic criteria at the time of the project's implementation and believe that they had had the good fortune to improve their economic status during the intervening years.

The informal process of selecting recipients may be appropriate in places such as the Grenadines where communities are small enough that each potential recipient would be known by at least one committee member who would be aware of the applicant's financial situation and of the household's proximity to either the public water supply or that of a neighbor willing to share excess water in times of need. It is unfortunate that there do not seem to have been clear guidelines for making recipient choices. Because of the general lack of record keeping associated with this project, including missing records and

undated reports, only a very incomplete and disjointed account of the project's implementation can be reconstructed.

There was some confusion about the project's ultimate scale. Documents prepared by CCC and SVGCC do not imply that this was to be a pilot project. However, many people with whom I spoke, including former committee members, were under the impression that SVGCC and/or CCC was running this as a pilot to see how the tanks would work. They believed a second project would follow shortly after the completion of the first. This misunderstanding may have resulted because people misinterpreted CCC's intent to mean that more tanks would be built if these proved to be durable.

Community Participation

It has become obvious to others who are involved in small self-help water development projects that it is necessary to expand the scope of community participation beyond that of merely supplying labor (Karp & Cox, 1982; Chauhan, 1983; Whyte, 1986; UN, DTCD, 1990). It is necessary to keep in mind the fact that this project was proposed and implemented when the concept of community participation was just developing and it was not promoted as incorporating this concept. It did, however, employ one component, self-help, that is suggested in the practice of community participation. To demonstrate how increased community participation might have benefited this project, it is necessary to first evaluate aspects of community participation as they would relate to this project. Keeping in mind that rainwater harvesting is a long-established method of water collection in the St. Vincent Grenadines and that financial constraints eliminated the possibility of constructing large concrete tanks, it may not have seemed to have been necessary to enlist the community in the choice of technology. However, more involvement on the part of recipients may have increased their understanding of the ferrocement technology and enabled them to be more proactive in quality control once informed of design standards. It may be appropriate to revitalize *maroons*, a cultural practice once prevalent throughout the Caribbean in which West Indians would cooperate to complete a large work project of one of them such as building a house or clearing a garden space (Pulsipher, 1996). The one person who benefited from the day's labor would repay the others by putting on a good feed at the end of the day and would be expected to participate in a *maroon* organized by any of those participating. The chore of building the tanks then becomes a social event which fosters community spirit and the cooperative effort increases the sense of ownership of the final product leading to improved quality and maintenance, as seen in Guatemala's Aqua de Pueblo Project (Cox & Karp, 1982).

The organization of local oversight committees on each of the four islands was a commendable attempt at involving the community in local project administration. However, promoting the involvement of local organizations and the development of ongoing community groups might have increased the sustainability of the tanks. Two major practices that enhance project success are (1) making sure that participants and community groups become responsible for the maintenance and repair of the water tanks

and, (2) providing guidelines, training and tools for those individuals, particularly the women, for these tasks (Kerkvoorden, 1982; Schiller, 1982; Pacey, 1977; Appan & Wing, 1987; Sornjitti, 1987). Implementing these and other community participation practices would have reduced the number of tank problems such as leaks and missing or non-functioning components.

Efficiency

The efficiency of the project administration is difficult to assess primarily due to the lack of documentation available to me. It took one year and eight months to complete the construction of 51 ferrocement water tanks on four closely spaced islands. Delays were caused by the need to make alternate arrangements to ship materials when the originally planned transport method failed (Mason, 1985; SVGCC a, no date). Additionally, new masons had to be found after the project had started when the originally chosen masons, trained earlier and expected to participate in this project, did not follow through. Overall, considering the setbacks, this project seems to have been completed within a reasonable length of time.

Local Administration

The degree of involvement of the oversight committee members varied. Ms. Ella Roache, from Mayreau, is a very dynamic person who seems to have a knack for getting people to cooperate with her. I witnessed this first-hand when we met, briefly, as she boarded the mail boat off Mayreau when I was deboarding. In all the confusion of loading and off-loading of supplies and people, she directed the motor launch crew to make room for my baggage and myself. She was very active as the Mayreau Committee Coordinator. She met with the SVGCC in Kingstown, St. Vincent on several occasions "whenever relevant matters were to be clarified" (SVGCC a, no date) and single-handedly resolved the material transportation dilemma for Mayreau. There was some delay in the progress of the project in Canouan when the oversight committee chairperson was unable to travel to Union to sign bank documents. I assume there was no bank in Canouan at the time the project was implemented. The undated *Progress Report Number Four* states that project monitoring and reporting from Canouan were via the mail boat (SVGCC a, no date). I assume that this was done through written correspondence since the same report states that the chairperson from Canouan had made only one trip to St. Vincent to discuss the progress of the project.

The varied level of commitment and availability of committee members is inevitable when committees are solely made-up of volunteers who have other responsibilities and commitments. Ms. Roache routinely makes frequent trips to St. Vincent, so it was not much out of her way to make progress reports to the SVGCC during her visits. Her dynamic personality contributed to her ability to resolve problems. I never met Mr. Sandy, Committee Chair from Canouan, but understand that he an active businessperson and perhaps too busy to be as attentive to details as was Ms. Roache. The inclusion of a full-time, paid, on-site project coordinator to pick-up the slack might have lessened delays caused by the

unavailability of volunteer committee members. Additionally, this person could have been responsible for other project administrative duties such as monitoring tank construction, material inventory control and tank inspection.

CHAPTER VII
CONCLUSION

Overall, the SVGCC/CCC Project in the St. Vincent Grenadines was successful in introducing a low-cost method of rainwater harvesting to the islands and assisting many of the poorest households by providing individual water supply. This thesis does, however, reveal many lessons that can be learned from certain problems associated with this project.

One of the positive outcomes of my work has been the use of a tank water balance as an analytical tool. Calculating and graphing monthly time period tank water balances proves to be a relatively simple and extremely helpful method for analyzing and visualizing the interacting factors of rainfall variability, contributing roof area, household size and water consumption habits.

This study reaffirms Winarto's (1987) theory that, after considering the financial constraints of a project, it is best to size the water storage tank to the area of the contributing roof. This is substantiated by the results of the tank water balances and the reports of sufficiency and overflowing by householders. In this study, sufficiency and overflowing increased as cra's increased. Daily rainfall data for each of the four islands over several consecutive years are needed to develop a more accurate estimate of the water yield from contributing roof areas. I maintain that gutters need to be installed on all accessible house roof slopes for maximum water collection efficiency.

Water storage capacity, in most instances studied, needs to be substantially greater to meet demand. Increased tank capacity would also reduce the reported incidence of overflowing reported. The amount of rain water captured and stored by this project was somewhat limited by the size of existing roofs and by the capability of current ferrocement designs. A similar study of the sufficiency of the larger capacity government-built tanks would help to determine whether they offer notable increase in efficiency. However, it is reasonable that tank water storage not reach 100% reliability in the Grenadines where, in most cases, there is a source of supplementary water within a reasonable distance. Taking into account the facts that it is not economically prudent for the government or funding groups to construct water tanks large enough to provide sufficient water year-round and that demand is increasing through population increases in the St. Vincent Grenadines, consideration could be given to installing additional household roof rainwater harvesting systems and rain water harvesting systems on community buildings for potable uses, and installing more brackish wells to provide supplementary water for non-potable use.

Because tanks for the smallest households with the smallest contributing roof areas overflow even during the most severely dry years, cooperative storage might be appropriate. Where it is logistically possible, consideration could be given to installing one water storage tank to be shared by two households. Using a tank larger than the SVGCC/CCC Project, one of the two households would need to consist of only one member while the second would need to be relatively small. A water balance could be calculated to

determine the maximum size of the second household. Water yield from both roofs could contribute to the storage, and efficiency would be improved by reducing the incidence of overflowing of the one-person system. I have seen a similar arrangement in Carriacou, Grenada.

Overall, the use of ferrocement to construct water storage tanks is an appropriate means of providing water in the Grenadines. The basic skills needed are readily adaptable for self-help projects and can be easily adopted for use by individuals and local masons. The tanks are economical to construct relative to other options in areas where there is no exploitable ground water and where the higher cost of constructing concrete block tanks is beyond the means of many individuals and funding sources. However, care must be taken to assure that materials used are of the highest possible quality and construction techniques are carefully adhered to, otherwise leaks will develop and useful tank life will be severely reduced.

The major goals set by the CCC for this project have been met: the water supply situation of some of the poorer households in the Grenadines has improved and the technology has been copied. Unfortunately, not all of the originally constructed tanks are operating at their full potential. At this point in time, SVGCC and CCC need to return to the Grenadines to make the necessary arrangements for tank repairs so that recipients can enjoy the full benefits of having a properly operating rainwater cistern.

The design has been improved upon and replicated in the St. Vincent Grenadines, albeit not to the extent hoped for, by the Government of St. Vincent and the Grenadines and by individuals independent of this project.

Secondary project objectives as revealed in conversations with S. Conrad Mason and from the article published in *Christian Action* ("Technology Transfer: ...," 1982) were partly met. The quantity of water in the St. Vincent Grenadines has increased as a result of this project, and it could be deduced that the status of recipients who have functioning water tanks has increased as the result of tank ownership. To assess improvements in water quality, the project design needed to have included a method of monitoring the water quality of the project-built tanks and of other sources of water in the Grenadines for comparison. Other indirect objectives, with respect to health and personal hygiene practices and brown water use may not be relevant for the St. Vincent Grenadines due to the sophistication of the population and the customary limited water use.

This follow-up study of the 1985-86 SVGCC/CCC Project illustrates the importance that a standard be set to include financing and guidelines for a follow-up and monitoring component in externally funded development projects. This component is often neglected by project planners (Pacey, 1986); thus, this omission is not unique to this project. Ongoing monitoring that starts during the project implementation will point out any defects in the tanks and also deficiencies in tank maintenance. The ongoing presence of a project representative would have the secondary benefit of keeping dialog open between the recipients and the project administrative organizations. In this project, such communication could have helped alleviate some of the controversy regarding participant choice and the confusion regarding the scope of the project.

Additionally, this study points out the need for comprehensive community participation to improve the quality of the finished product and the need for ongoing maintenance.

BIBLIOGRAPHY

BIBLIOGRAPHY

Ackie, Daphne, former Oversight Committee Chair, Union, SVG, 1995. Author interview, July 27.

Ackie, Fitsroy, participating mason in the SVGCC/CCC Project, Union, SVG, 1995. Author interview, July 29.

Appan, Adhityan and Lee Kam Wing, 1987, A Total Approach Towards the Establishment of Rain Water Cistern Systems in Developing Countries, *Proceedings of the Third International Conference on Rain Water Cistern Systems,* International Development Research Centre.

Astwood, Lea L. E., 1990, Discussion on Session IV, Rainwater Catchment Systems, *Water Resources Management Techniques for Small Island Countries, Report of an Inter-Regional Seminar*, Commonwealth Science Council, London.

Ativon, Kodjo L., 1988, Measures to be Taken to Ensure Adequate Drinking Water Supply and Sanitation, *Promotion of Women's Participation in Water Resources Development Report of the Seminar, Bamako, Mali*, UN, Department of Technical Co-operation for Development, New York.

Belmar, Herman, School teacher, Bequia, 1995. Author interview, July 15.

Blackman, S.A., 1987, Experiences With Transportation of Water by Tanker, *Non-Conventional Water Resources Use in Developing Countries*, UN, Department of Technical Co-operation for Development, New York.

Browne, Honorable Stephanie, Government of St. Vincent and the Grenadines, Representative from the Southern Grenadines, Union, SVG, 1995. Author interview, July 25.

Caldwell, John, Proprietor of Palm Island Resort, Palm Island, Grenadines, 1995. Author interview, July 27.

Canadian High Commission, no date, *Project Agreement*, Bridgetown, Barbados.

Caribbean Conference of Churches, no date, *Project Proposal*, Bridgetown, Barbados.

_____, 1984, *Progress Report: Ferrocement Water Tank Construction Project, St. Vincent, Grenadines,* October 15.

Caribbean Conservation Association, 1991, *St. Vincent and the Grenadines: Environmental Profile,* Caribbean Conservation Association, Barbados.

Chauhan, Sumi Krishna, 1983, *Who Puts the Water in the Taps? Community Participation in Third World Drinking Water, Sanitation and Health*, Earthscan, Washington, DC.

Chindaprasirt, P., I. Hovichitr & P. Wirojanagud, 1987, A Low Cost Rainwater Tank, *Proceedings of the Third International Conference On Rain Water Cistern Systems*, International Development Research Centre, Khon Kaen, Thailand.

Clarke, Robin, 1993, *Water*, MIT Press, Cambridge, MA.

"Community Participation: Key to Sustainability," 1993, *Raindrop; Rainwater Harvesting Bulletin,* Vol. 9, July.

Daquia, Olga, 1988, The Role of African Women in the Development and Management of Water Resources, *Promotion of Women's Participation in Water Resources Development; Report of the Seminar, Bamako, Mali*, UN, Department of Technical Co-operation for Development, New York.

Davis, Kortright, 1982, *Mission for Caribbean Change: Caribbean Development As Theological Enterprise*, Verlog Peter Lang, Frankfurt.

Deere, Carmen, Peggy Antrobus, Lynn Bolles, Edwin Melendez, Peter Phillips, Marcia Rivera & Helen Safa, 1990, *In The Shadows of The Sun*, Westview Press, Inc., Boulder, CO.

Desa, Yayasan Dian, 1981, Rainwater Collection Tanks Constructed on Self-Help Basis, *Journal of Ferrocement*, Vol. 11, No. 3, July.

DeSilva, Mark, 1995, Parish priest for the southern Grenadines, Kingstown, St. Vincent & the Grenadines, author interview, July, 6.

_____, no date, *Mayreau: An Island of Beauty*, unpublished brocure.

Doelhomid, Srimoerni, 1982, Rain Water Cisterns in Indonesia, *Proceedings of the International Conference on Rain Water Cistern Systems,* Honolulu, Hawaii.

Dunska, Krystyna, 1988, Women's Role in CIDA Projects, *Promotion of Women's Participation in Water Resources Development; Report of the Seminar, Bamako, Mali*, UN, Department of Technical Co-operation for Development, New York.

Falkland, Anthony, 1992, *Small Tropical Islands: Water Resources of Paradise Lost*, International Hydrological Programme Humid Tropics Programme Series No. 2, UNESCO, Paris.

_____, editor, 1991, *Hydrology and Water Resources of Small Islands: A Practical Guide*, UNESCO, Paris.

Falkland, Anthony and J. P. Brunel, 1993, Review of Hydrology and Water Resources of Humid Tropical Islands, *Hydrology and Water Management in the Humid Tropics*, Cambridge University Press, Great Britain.

Fuaud, Nik, 1984, Suitability of Rain Water Cistern Systems in Malaysia, *Proceedings of the Second International Conference on Rain Water Cistern* Systems, St. Thomas, U.S.V.I..

Goh, K.C. and Mahyuddin Ramli, 1987, Rain Water Cistern System for the Rural Areas of Kedah, Malaysia, *Proceedings of the Third International Conference on Rain Water Cistern Systems,* International Development Research Centre, Khon Kaen, Thailand.

Gould, John E., 1987, An Assessment of Roof and Ground Catchment Systems, *Proceedings of the Third International Conference On Rain Water Cistern Systems*, International Development Research Centre, Khon Kaen, Thailand.

Government of St. Vincent and the Grenadines, 1983a, Bequia map

_____, 1983b, Canouan map.

_____, 1983c, Mayreau map

_____, 1983d, Union map.

_____, Central Water and Sewer Authority, no date, *Rainfall Information Sheets*, Kingstown, St. Vincent.

_____, Civil Aviation Department, 1995, J. F. Mitchell Airport, Bequia, Personal Correspondence, October 13.

_____, Tourist Bureau, no date, *Bequia Information Sheet.*

Grover, Brian, 1982, Operation and Maintenance of Water Supply and Sanitation Systems, *Water Supply and Sanitation in Developing Countries,* Ann Arbor Science, MI.

Haan, S. C. de, 1987, Dominica: Caribbean Experiences With Transporting Water by Tanker, *Non-Conventional Water Resources Use in Developing Countries*, United Nations Department of Technical Co-operation for Development, New York.

Hadwen, Peter, 1987a, Caribbean Islands: A Review of Purpose Built Catchments, *Non-Conventional Water Resources Use in Developing Countries*, UN, Department of Technical Co-operation for Development, New York.

_____1987b, Rain-Water Harvesting: An Overview, *Non-Conventional Water Resources Use in Developing Countries*, UN, Department of Technical Co-operation for Development, New York.

Haebler, R. H. & D. H. Waller, 1987, Water Quality of Rain Water Collection Systems in the Eastern Caribbean, *Proceedings of the Third International Conference On Rain Water Cistern Systems*, International Development Research Centre, Khon Kaen, Thailand.

Hall, William, Peace Corps Volunteer, Union, SVG, 1995. Telephone interview, October 21.

Harrison, W. James, Research Engineer, Smith and Nephew Richards, Inc., Memphis, TN, 1995. Telephone interview, August 20.

Hatch, Reverend Andrew, former executive in the Caribbean Conference of Churches, Bridegetown, Barbados, 1995. Author interview, August 11.

Headley, Oliver, 1993, What Are Solar Stills?, *Trinidad and Tobago Review*, p. 48, December, 1993.

Hofkes, E.H., ed., 1983, *Small Community Water Supplies*, International Reference Centre for Community Water Supply and Sanitation, The Hague.

Htoon, Mr., UN, Volunteer, Government of St. Vincent Water and Sewer Authority, Kingstown, SVG, 1995. Author interview, July 7.

Huisman, L., N. Van Gorkum, K. Kempenaar, 1982, Water Supply and Treatment, *Appropriate Methods of Treating Water and Waster Water in Developing Countries*, Ann Arbor Science, MI.

Jenkins-McLean, Terri, 1991, Lessons Learned From A Third World Water and Sanitation Project, *Journal of Environmental Health*, Vol. 54, Spring, pp. 34-38.

Johnson, Brian, Forestry Division, GSVG Ministry of Agriculture, Kingstown, SVG., 1995. Author interview, July 6.

Johnson, Kirsten, 1982, Rain and Stormwater Harvesting in Rural Areas, *Proceedings of the IVth World Congress International Water Resource Association*, Tycooly International Publishing, Ltd., Dublin.

Kane, Aissata, 1988, Presentation by Mauritania, *Promotion of Women's Participation in Water Resources Development; Report of the Seminar, Bamako, Mali*, UN, Department of Technical Co-operation for Development, New York.

Karp, Andrew and Stephen Cox, 1982, Building Water and Sanitation Projects in Rural Guatemala, *Journal of American Water Works Association*, Vol. 74, No. 4, pp. 163-169, April.

Kerkvoorden, Ron van, 1982, Rainwater Collectors for Villages in West Java, Indonesia, *Proceedings of the International Conference on Rain Water Cistern Systems*, Water Resources Research Center, University of Hawaii at Maoa, Honolulu, HI.

Latham, Brian & Eric Schiller, 1987, Rainwater Collection Systems: A Literature Review, *Proceedings of the Third International Conference On Rain Water Cistern Systems*, International Development Research Centre, Khon Kaen, Thailand.

Lee, S. L., P. Paramasivam, K. C. G. Ong & K. H. Tan, 1987, Ferrocement Cylindrical Tanks for Rainwater Collection in Rural Areas, *Proceedings of the Third International Conference On Rain Water Cistern Systems*, International Development Research Centre, Khon Kaen, Thailand.

Lewis, David, Chief Engineer, National Water and Sewer Authority, Government of Grenada, 1994. Author interview, June 13.

Macpherson, John, 1980, *Caribbean Lands*, Longman Caribbean, Jamaica and Trinadad.

Mason, S. Conrad, Regional Programme Co-ordinator, CCC, Bridgetown, Barbados, 1995. Personal correspondence, August 11.

_____, Bridgetown, Barbados, 1994. Author interview, June 15.

_____, 1985, *Travel Report*, July 7-15.

McAfee, Kathy, 1991, *Storm Signals*, South End Press in Association with Oxfam America, Boston, MA.

McPherson, H. J. & J. Gould, 1987, Kenya and Botswana: Experience with Rain-Water Catchment Systems, *Non-Conventional Water Resources in Developing Countries*, UN,, New York.

Nebel, Bernard and Richard Wright, 1993, *Environmental Science: The Way The World Works*, Prentice Hall, NJ.

Pacey, Arnold, 1986, *Rainwater Harvesting*, Intermediate Technology Publications, London.

Pacey, Arnold, editor, 1977, *Water for the Thousand Million,* Pergammon Press, Oxford, England.

Paulsen, Keith, 1984, *Ferrocement Water Tank Project: Grenadines*.

Perrens, S. J., 1982, Design Strategy for Domestic Rainwater Systems in Australia, *Proceedings of the International Conference on Rain Water Cistern Systems, Honolulu, HI.*

Pickford, John, Peter Barker, Adrian Coad, Margaret Ince, Rod Shaw, Brian Skinner & Michael Smith, eds., 1994, *Water, Sanitation, Environment and Development*,Intermediate Technology Publications, London.

Piggott, Terry L., Ian J. Schiefelbein and Mark T. Durham, 1982, Application of Gould Matrix Technique to Roof Water Storage, *Proceedings of the International Conference on Rain Water Cistern Systems, Honolulu, HI.*

Pinfold, John V., Nigel J. Horan, Wanpen Wirojangud & Duncan Mara, 1993, The Bacteriological Quality of Rainjar Water in Rural Northeast Thailand, *Water Resources*, Vol. 27, No. 2, pp. 287-232.

Pompe, C. L. P. M., 1982, Design and Calculations of Rain Water Collection Systems, *Proceedings of the International Conference on Rain Water Cistern Systems, Honolulu, HI.*

Price, Neil, 1988, *Behind the Planter's Back*, MacMillan Caribbean, London.

Pulsipher, Lydia Mihelic, Professor University of Tennessee, 1996, personal correspondence, April 5.

Ray, Carl, Sales Technician, American Limestone Company, Knoxville, TN, 1995. Author interview, October.

Reynolds, Colin, 1990, Rainwater Catchments on Tuvalu, UN, Department of Economic and Social Affairs, 1970, *Solar Distillation as a Means of Meeting Small-Scale Water Demands*, UN, New York.

Riney, Thane, 1972, Experiments with the Use of Case Histories in an Ecology Seminar, *The Careless Technology*, M. Taghi Farvar & John P. Milton, eds., Natural History Press, New York.

Robinson, E.H., no date, *Construction Manual for 3500 gallon Ferrocement Water Tank*, Cedar Press, Bridgetown, Barbados.

Rodda, John C., 1995, Wither World Water, *Water Resources Bulletin*, Vol. 31, No. 1, pp. 1-7.

Ruskin, Robert H., J. Hari Krishna & Giglia A. Beretta, 1992, Detection of Legionella-like Organisms in Cistern Water, Using a Membrane Filter Technique, *Caribbean Journal of Science*, Vol. 28, No. 3-4, pp. 134-138.

Sare, Adelaide, 1988, Water Resources Development: Micro-Projects Programme, *Promotion of Women's Participation in Water Resources Development; Report of the Seminar, Bamako, Mali*, UN, Department of Technical Co-operation for Development, New York.

Schiller, Eric J., 1982, Rooftop Rainwater Catchment Systems for Drinking Water Supply, *Water Supply and Sanitation In Developing Countries*, Ann Arbor Science Publications, MI.

Schiller, Eric J. & Ronald L. Droste, 1982, *Water Supply and Sanitation in Developing Countries*, Ann Arbor Science Publications, MI.

Schultz, Christopher, 1996, *The Carriacou Hypothesis: Bottomless Stacked Pots, A Study in Amerindian Fresh Water Procurement,* unpublished M.S. thesis, Dept. of Geography, University of Tennessee, Knoxville, TN.

Simmons, Hyacinth, participating mason in the SVGCC/CCC Project, Canouan, St. Vincent and the Grenadines, 1995. Author interview, July 18.

Skoda, John D. & Colin Reynolds, 1993, Rain Water Harvesting On Coral Atolls, *Raindrop*, Vol. 9, July.

Sornjitti, Pairojana, 1987, Thailand: Rain-water Tank Project of the Population and Community Development Association, *Non-Conventional Water Resources Use in Developing Countries*, UN, Department of Technical Co-operation for Development, New York.

Speth, James Gustave, 1994, *Administrator's Statement for World Water Day*, UN, Development Programme.

St. Vincent and the Grenadines Christian Council, a., no date, *Progress Report No. (4) Four.*

_____, b., no date, *Final Report.*

Stephens, Vilbert Dennys, 1991, *Canouan: A Critical Description of Selected Features of Its Social History*, B.A. Thesis, Theology Department, University of West Indies.

Surwavuba, Melanie, 1988, Structure and Type of Participation by Women and the Community, *Promotion of Women's Participation in Water Resources Development; Report of the Seminar, Bamako, Mali*, UN, Department of Technical Co-operation for Development, New York.

"Technology Transfer: Water Tanks," 1982, *Christian Action: The Monthly Newsletter of the Caribbean Conference of Churches and Its Commissions on Renewal and Development*, August, Vol. 8, No. 5.

"There is Water," 1995, *Boston Sunday Globe*, page A54, June 6, Boston, MA.

Tourist Bureau, Government of St. Vincent and the Grenadines a., no date, *Bequia Information Sheet.*

_____b., no date, *Union Information Sheet.*

UN, Department of Economic and Social Affairs, 1970, *Solar Distillation As A Means of Meeting Small-Scale Water Demands*, UN, New York.

UN, Department of Technical Co-operation for Development, 1990, *Water Resources Development in the Caribbean: Project Findings and Recommendations*, UN, New York.

UN, Department of Technical Co-operation for Development a., 1989, *Legal and Institutional Factors Affecting the Implementation of the International Drinking Water Supply and Sanitation Decade: Natural Resources/Water Series No. 23*, UN, New York.

UN, Department of Technical Co-operation for Development b., 1989, *Participation of Women's Participation in Water Resources Development*, UN, New York.

UN, Department of Technical Co-operation for Development, 1988, *Water Resources Planning to Meet Long-Term Demand: Guidelines for Developing Countries*, UN, New York.

UN, Department of Technical Co-operation for Development, 1987, *Non-Conventional Water Resources Use in Developing Countries*, UN, New York.

Wall, Jeanette, no date, *Rainfall: Union Island: 1969-1995*, Union, SVG.

Waller, D. H., 1982, Rain Water As a Water Supply Source in Bermuda, *Proceedings of the International Conference on Rain Water Cistern Systems*, June, Water Resources Research Center, University of Hawaii at Maoa, Honolulu, HI.

Whyte, Anne, 1986, *Guidelines for Planning Community Participation Activities in Water Supply and Sanitation Projects*, World Health Organization, Geneva.

Williams, Carlton, Executive Secretary of the St. Vincent and the Grenadines Christian Council, Kingstown, SVG, 1995. Author interview, July 9.

Winarto, 1981, Rainwater Collection Tanks Constructed on a Self-Help Basis, *Journal of Ferrocement*, Vol. 11, No. 3, Pp. 247-254.

Winarto, 1987, Rural Rain Water Cistern Design in Indonesia, *Proceedings of the Third International Conference On Rain Water Cistern Systems*, International Development Research Centre, Khon Kaen, Thailand.

World Health Organization, *National Decade Plans: Eight Questions They Answer*, 1982, WHO, Geneva.

Wright, David, Senior Field Technician - International Rescue Committee, Belize, 1994. Personal correspondence, March 13.

Yoganarasimhan, G. N., 1987, Rural Water Supply Project, Nusatenggara Timur-Indonesia, *Proceedings of the Third International Conference On Rain Water Cistern Systems*, International Development Research Centre, Khon Kaen, Thailand

APPENDICES

APPENDIX A

CCC PROJECT PROPOSAL

Project Projposal

Title:	*Ferrocement Water Tank Construction Programme - St. Vincent Grenadines.*
Executing Organisation:	*St. Vincent and the Grenadines Christian Council in association with the Caribbean Conference of Churches*
Contact Persons/ Addresses:	*(1) Liley Cato* *Executive Secretary* *St. Vincent and the Grenadines Christian Council* *P.O. Box 445* *Kingstown* *St. Vincent Tel. 71809* *(2) S. Conrad Mason* *CATC Programme Coordinator* *Caribbean Conference of Churches* *P.O. Box 616* *Bridgetown* *Barbados Tel. 427-2681*
Request:	*Grant ~~BDS~~EC$101 300 00*
Goal:	*To improve the water supply situation affecting poorer families in the St. Vincent Grenadines.*
Purpose:	*To provide financial assistance to at least 50 poor families in the St. Vincent Grenadines who wish to build their own ferrocement tanks to conserve and store water for domestic use.*
Objectives:	*1. To facilitate the construction of 50 ferrocement water tanks in the islands of Bequia (10), Canouan (15), Mayreau (10), and Union (15).* *2. To further promote the construction and use of ferrocement water tanks as a low cost method of conserving and storing water for domestic use in these islands.*
Duration:	*1 year.*
Background:	*The St. Vincent Grenadines are a string of tiny islands extending south of St. Vincent and lying between that island and Grenada. There are six inhabited islands, two of which are for all acts and purposes resorts.* *It is the other four islands that have given the St. Vincent Christian Council and the CCC cause for serious concern. The islands are Mayreau, Canouan, Union, and Bequia.*

/2..

Background (Cont'd..)

People on these islands make their living primarily from fishing and working as sailors on boats ranging from yachts and schooners to the supertankers that ply the trans Atlantic routes.

But there are very few inhabitants who are wealthy and the majority are at or just above the subsistence level.

The islands are all drought prone with rainless periods of between five to eight months of the year. As a result, one of the most serious problems facing the inhabitants is the lack of adequate supplies of potable water.

The only consistent source of potable water is rain water which must be collected in tanks, cisterns, drums or whatever container is available when the rains do fall. This must be carefully used almost hoarded till the next rains.

A recent survey has been carried out on the situation in the four islands as it relates to the question of water supply.

Mayreau: Population - approximately 150.
A community reservoir was built in 1974 through the efforts of a Roman Catholic monk Pere Divonne. Financial assistance for the construction of this tank was provided by the St. Vincent Christian Council. The reservoir which was a major improvement in the water situation is still insufficient for the total needs of the population. The situation sometimes beccomes so bad that water must be sent by boat from the mainland.

Canouan: Population - 900-1000.
There are several storage tanks maintained by Government serving schools, a community centre, the police station and community catchments with a total capacity of 14 000 gallons. At present all of the tanks are in a state of disrepair. Two of these tanks are partially usable. It often becomes necessary for a Government vessel to bring water to relieve the situation.

Union: Population -Approximately 1800.
There are two public reservoirs serving the two settlements on the island. Ashton, the larger of the two settlements has a reservoir that goes nearly dry every year. A reservoir located in the other settlement serves a new clinic primarily.

3/..

Background (Cont'd..)

Bequia: Population - Approximately 7 000 - 8 000.
Paget Farm area - 3500 - 4000
Port Elizabeth Area - 2500 - 3000

Of the several Government owned reservoirs, only one in Hamilton (near Port Elizabeth) dispenses water to the public. Paget Farm, the single most populated area and fish centre has no viable public reservoir and is several miles away from Hamilton. Many of the public reservoirs and catchments are poorly maintained and are in a state of disrepair.

The situation which exists in relation to public water supplies generally, has led to a lowering of health standards and to stagnation in the social and economic status of the lower income group.

A private water tank is therefore something which every family who experiences the problems of inadequate water supplies year after year is eager to have. It would greatly reduce if not eliminate the present hardships and in particular enable them to use the time spent collecting and transporting water in more productive ways.

There exist on the islands a number of families who already have their own tanks or have plans and can afford to build one. There are however some families who are very poor and have no realistic hope of ever being able to afford proper or near adequate water storage facilities. They barely subsist with incomes ongoing between EC$800 and $1100 per annum which they obtain from fishing occasional day labour, or, relatives abroad.

The Caribbean Conference of Churches, an ecumenical organisation, committed to the development of poorer people in the region has been involved in finding solutions to the water problem in the Grenadines since 1974 when funds were provided to the St. Vincent Christian Council for the construction of a public reservoir in Mayreau.

The problem of inadequate water supplies in the islands has been repeatedly identified as the major problem facing people in meetings sponsored by the St. Vincent Christian Council and the CCC on the role of the Church in social change in the islands.

In an effort to assist the islanders, the CCC investigated available technologies and the possibility of introducing a relatively cheap and durable water storage unit. In addition,

it should be less prone to cracking than conventional tanks and if cracking occurs, it should be easier to repair. It was found that ferrocement water tanks fitted the criteria set. The technology was not known in the Grenadines or for that matter, in St. Vincent.

In a project designed to introduce and promote the technology 4 x 3,500 gal. tanks were constructed, one on each of the four islands, in early 1982.

The prototypes built were for demonstration and testing and to train local masons in the construction technique. The technology which comprised a cyclindrical skeleton of wire mesh and steel with plastered rather than poured cement has proved to be less expensive than conventional tanks by as much as 40% and has had reasonably good acceptance.

A number of families belonging to the lower income group have since expressed interest in obtaining their own ferrocement tank and have indicated their willingness to assist in their construction.

Rationale:

Although ferrocement water tanks with a capacity of at least 3 500 gallons are considered adequate for average sized families the cost of these tanks is still out of reach of the poorer families in the Grenadines. It is therefore necessary to provide some financial assistance. This is needed to meet the cost of imported materials and to pay for the technical expertise required to supervise the construction of the tanks. The families will provide labour and locally available materials (stones and sand) as their contribution.

The provision of financial assistance in the form of a grant rather than a loan is seen as the only practical way of helping members of the target group to own their own tanks.

The construction of additional tanks on the islands is also considered necessary to further demonstrate and promote the technology.

The Project:

The project will assist at least 50 of the poorest families in the four islands to build 3 500 gallon ferrocement water tanks for their own uses through the provision of grant funding. The number of tanks to be built on each island will be as follows:

Bequia	- 10	Mayreau	- 10
Canouan	- 15	Union	- 15

The Project (Cont'd..)

The families who will be benefitting from the programme will be selected from among members of the target group by a special Committee comprising knowledgeable and respected persons and residents of the islands.

A list and background information on the persons making up the Committee is given in Appendix 1. The following considerations will be used as the criteria for the selection of the beneficiaries.

i) neediest cases on an individual basis;

ii) practicability and willingness of two or more families sharing the use of a tank.

The families selected to benefit from the programme will be asked to collect the necessary locally available materials, prepare the site and assist in the construction of their tanks. The technical expertise for the construction of the tanks will be drawn from among the core number of masons trained on each island during the initial training and demonstration project.

The project will be implemented over a period of 1 year.

Project Administration/ Coordination: *The project will be administered by the St. Vincent Christian Council with the assistance of the special ferrocement water tanks construction Committee set up to implement the programme.*

The Council will assume responsibility for the disbursement of funds for the construction of the tanks to the special Committee who will coordinate and monitor the building activities as well as make payments for labour and materials purchased.

A number of visits to the islands by CCC/CATC personnel and Christian Council personnel will be made to finalise arrangements for the implementaiton of the project and to monitor its progress.

Estimated Costs per tank:	*E.C. Currency*
1. Materials - (Cement, wire mesh, steel to be purchased) and transportation	*1 400 00*
2. Materials - (Sand, rocks, gravel) (to be contributed by family)	*200 00*
3. Labour - (at $25 per day x 14 days) (to be contributed by family)	*350 00*
C/F	*1 950 00*

/6..

	B/F	1 950
Estimated Costs (Cont'd..)		
Technical expertise (& Supervisor)(at $40 per day x 14 days)		560 00
Total per tank		2 510 00
Total for 50 tanks		125 500 00
Form work (4 sets)(to be used for all the tanks on each island)		1 000 00
Sub Total		126 500 00
Overseas and local travel and subsistence		
(a) CCC/CATC Personnel - 3 x 2 weeks visits	1500 00	
(b) St. Vincent Xtian Council Personnel 3 x 2 weeks visits	800 00	2 300 00
Total		128 800 00
Contributors re funding		
Families		27 500 00 - 21%
Funding Agency		101 300 00
Total		128 800 00

APPENDIX B
RAINFALL TABLES

BEQUIA

Central Water & Sewer Authority, GSVG.

	1968	1969	1970	1971	1973	1975	1976	1977	1995
January	66	260	75	80	91	56	96	21	
February	22	33	33	119	73	53	90	4	
March	109	53	54	36	11	23	21	0	
April	61	91	35	22	69	72	22	62	18.2
May	105	146	77	57	47	19	80	58	25.5
June	206	253	300	49	132	29	51	107	168.6
July	61	100	366	135	55	35	122	134	105.6
August	164	243	215	259	89	262	184	141	204.2
September	211	174	180	214	83	138	140	263	131.3
October	138	175	184	229	203	337	169	348	
November	187	124	166	319	154	147	116	198	
December	147	163	217	320	33	188	254	86	
Year total	1477	1815	1902	1839	1040	1359	1345	1422	

	MEAN	MEDIAN	MAXIMUM	MINIMUM
January	93	78	260	21
February	53	43	119	4
March	38	30	109	0
April	50	61	91	18.2
May	68	58	146	19
June	144	132	300	29
July	124	106	366	35
August	196	204	262	89
September	170	174	263	83
October	223	194	348	138
November	176	160	319	116
December	176	176	320	33
Year total	1524.88	1449.5	1902	1040

*1995 data from the Civil Aviation Dept. at the J. F. Mitchell Airport, Bequia.

All other data from the Central Water and Sewer Authority, GSVG.

rainfall amounts in millimeters

UNION RAINFALL

Central Water & Sewer Authority, GSVG

	1968	1969	1970	1971	1972	1973	1975	1976	1977	1978	1979	1980	1981	1982	1986
JAN.	31	213	108	71	172	106	56	48	17	37	131	154	29	20	12
FEB.	35	44	71	74	173	60	61	169	89	3	19	100	37		7
MAR.	93	8	80	44	45	11	27	145	64	54	118	29	8		5
APR.	101	33	35	9	111		58	68	23	28	132	17	162		7
MAY	102	81	118	116	41	53	41	70	84	31	80	20	161		
JUNE	94	300	235	23	60	63	41	116	215	157	180	221	74		29
JULY	56	40	332	108	149	59	52	116	106	483	559	126	62		
AUG.	104	300	409	45	172	163	367	75	124	466	419	261	102		211
SEPT.	150	146	276	218	37	36	134	198	267	86	207	73	76		
OCT.	262	114	409	219	127	236	227	146	239	180	313	205	64		
NOV.	128	347	292	146	64	228	273	174	297	445	339	59	66	167	
DEC.	105	177	114	145	115		175	242	75	55	372	181	115		
Total	1261	1803	2479	1218	1266		1512	1567	1600	2025	2869	1446	841		

	MEAN	MEDIAN	MAXIMUM	MINIMUM
JAN.	80	112.5	213	12
FEB.	60	88	173	3
MAR.	57	75	145	5
APR.	60	84.5	162	7
MAY	77	90.5	161	20
JUNE	129	161.5	300	23
JULY	173	299.5	559	40
AUG.	230	255.5	466	45
SEPT.	146	156	276	36
OCT.	211	236.5	409	64
NOV.	216	203	347	59
DEC.	156	213.5	372	55
Total	1662	1911.5	2867	956

*Rainfall amounts in millimeters

UNION RAINFALL

Wall, Union, SVG

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
January	35	25	48	83	27	29	39	28	39	
February	20	62	58	22	33	39	171	20	6	
March	12	24	31	11	54	18	52	31	51	
April	9	12	47	27	31	52	25	29	14	
May	47	20	35	29	115	35	40	35	33	
June	111	32	30	42	45	40	70	104	107	
July	162	54	85	34	79	85	106	84	278	
August	258	126	81	93	131	230	62	127	206	
September	111	91	64	155	53	89	99	177	77	
October	193	83	80	182	174	233	114	144	118	160
November	103	132	48	112	97	203	86	95	121	297
December	105	88	78	36	27	125	145	36	31	270
Yearly total	1166	724	685	826	866	1178	1009	910	1081	
	1981	1982	1983	1984	1985	1986	1992	1993	1994	1995
January	30	16	74	80	56	40	47	61	55	30
February	42	44	2	70	41	28	72	66	65	41
March	18	20	17	40	25	29		48	0	31
April	102	2	0	44	114	31	16	9	17	28
May	88	25	173	76	10	33	97	31	9	6
June	190	54	132	75	70	181	315	149	91	117
July	92	78	186	135	252	39	55	115	62	122
August	168	248	195	116	221	211	185	213	189	
September	141	176	301	145	99	302	193	91	113	
October	64	185	130	117	165	157	39	184	114	
November	88	136	125	187	98	93	235	195	86	
December	63	102	72	128	161	76	69	48	78	
Yearly total	1086	1086	1407	1213	1312	1220		1210	879	
Rainfall in millimeters										

Union Rainfall Statistics
Data from Wall
1969-86, 1992-94

	MEAN	MEDIAN	MAXIMUM	MINIMUM
January	50	35	83	25
February	47	33	171	6
March	27	31	54	11
April	30	27	52	9
May	47	35	115	20
June	107	45	111	30
July	110	85	278	34
August	168	127	258	62
September	137	91	177	53
October	135	152	233	80
November	140	107.5	297	48
December	96	83	270	27
Yearly total	1093	910	1178	685

Rainfall in millimeters

			1995 Daily Rainfall Data: Bequia			
			collected at:			
			J. F. MITCHELL AIRPORT			
			GSVG			
DATE	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
1	-			1		
2	-		10.6			
3	-	3		4.4		2.5
4	1	2.5		18.5	13.4	
5	-				21	
6	3.1		6.2		10	0.5
7	-		3.5			3
8	-				21	
9	-	4.1	13.4	3.5	43.5	0.2
10	-		5.5	3		17
11	5.2		1.8			
12	-	1	0.1			
13	-					
14	-		7.8	1.3		
15	1.3		1.1	1.7	10	0.4
16	-		1.7	0.5	1.7	
17	-		34.6	0.7	13.3	
18	-		14.5			
19	-		24.5	5.3	17	
20	-	6.8	28.8	22.5		1.3
21	-	7.6	1.1			7.4
22	0.8			3.6	16.8	
23	-		4.1	8.5	7.2	72.4
24	-	0.5		13.7		6
25	4.8				25.6	
26	2			8.7		
27	-			3.1		0.6
28	-			4.1	3.7	
29	-		1.5			20
30	-		4.8	1.5		
31	-					
		-				
TOTAL	18.2	25.5	168.6	105.6	204.2	131.3
rainfall units: millimeters						

Data collected by author: summer 1995				
		BEQUIA		
Date	7/13/95	7/15/95	7/16/95	7/17/95
Storm length	3 min.	na	na	na
Rainfall	2 mm	4 mm	1 mm	3 mm
		CANOUAN		
	7/18/95	7/19/96	7/19/95	7/20/95
	5 min.	<5 min.	<10 min.	23 hrs.
	<1 mm	4 mm	2 mm	38 mm
		MAYREAU		
	7/22/95	7/23/95		
	na	na		
	4 mm	3 mm		
		UNION		
	7/27/95	7/29/95	7/30/95	
intermittent/all day		na	na	
	16mm	4 mm	<2mm	

	CANOUAN RAINFALL			
Central Water & Sewer Authority, GSVG				
	1968	1969	1970	1971
January		161	73	24
February		8	60	92
March		1	37	68
April		47	18	6
May		114	62	44
June		106	221	18
July		110	280	75
August	126	245	198	
September	52	107	163	
October	162	188	179	
November	60	162	156	
December		138	115	
Year Total		1387	1562	
rainfall in millimeters				

APPENDIX C

TANK WATER BALANCE SPREAD SHEETS

Union Government Data: Minimum annual rainfall

seven-person household

month	May	June	July	August	September	October	November	December	January	February	March
	1980										
mm rain	20	221	126	261	73	205	59	181	29	37	8
roof (square meters)	45	45	45	45	45	45	45	45	45	45	45
yield (liters)	720	7956	4536	9396	2628	7380	2124	6516	1044	1332	288
# days/month	31	30	31	30	31	31	30	31	30	31	31
# liters/day consumed	70	70	392	70	392	70	392	70	392	70	70
amount consumed	2170	2100	12152	2100	12152	2170	11760	2170	11760	2170	2170
yield - consumed	-1450	5856	-7616	7296	-9524	5210	-9636	4346	-10716	-838	-1882
change in tank supply	0	5856	0	7296	0	5210	0	4346	0	0	0
month's strart tank (liters)	0	0	5856	0	7296	0	5210	0	4346	0	0
deficit (liters)	1450	0	1760	0	2228	0	4426	0	6370	838	1882
overflow (liters)	0	0	0	0	0	0	0	0	0	0	0
carryover (liters)	0	5856	0	7296	0	5210	0	4346	0	0	0

Union Government Data: Minimum annual rainfall

seven-person household

month	April	May	June	July	August	September	October	November	December	January
mm rain	162	161	74	62	102	76	64	66	115	20
roof (square meters)	45	45	45	45	45	45	45	45	45	45
yield (liters)	5832	5796	2664	2232	3672	2736	2304	2376	4140	720
# days/month	28	31	30	31	31	30	31	30	31	31
# liters/day consumed	70	70	392	70	70	70	70	70	70	392
amount consumed	1960	2170	11760	2170	2170	2100	2170	2100	2170	12152
yield - consumed	3872	3626	-9096	62	1502	636	134	276	1970	-11432
change in tank supply	3872	3626	0	62	1502	636	134	276	1970	0
month's strart tank (liters)	0	3872	7498	0	62	1564	2200	2334	2610	4580
deficit (liters)	0	0	1598	0	0	0	0	0	0	6852
overflow (liters)	0	0	0	0	0	0	0	0	0	0
carryover (liters)	3872	7498	0	62	1564	2200	2334	2610	4580	0

Union Government Data: Minimum annual rainfall

seven-person household

month	May	June	July	August	September	October	November	December	January	February	March
	1980								1981		
mm rain	20	221	126	261	73	205	59	181	29	37	8
roof (square meters)	25	25	25	25	25	25	25	25	25	25	25
yield (liters)	400	4420	2520	5220	1460	4100	1180	3620	580	740	160
# days/month	31	30	31	30	31	31	30	31	30	31	31
# liters/day consumed	70	70	70	70	392	70	70	70	70	70	70
amount consumed	2170	2100	2170	2100	12152	2170	2100	2170	2100	2170	2170
yield - consumed	-1770	2320	350	3120	-10692	1930	-920	1450	-1520	-1430	-2010
change in tank supply	0	2320	350	3120	0	1930	0	1450	0	0	0
month's strart tank (liters)	0	0	2320	2670	5790	0	1930	1010	2460	940	0
deficit (liters)	1770	0	0	0	4902	0	0	0	0	490	2010
overflow (liters)	0	0	0	0	0	0	0	0	0	0	0
carryover (liters)	0	2320	2670	5790	0	1930	1010	2460	940	0	0

Union Government Data: Minimum annual rainfall

seven-person household

month	April	May	June	July	August	September	October	November	December	January
	1981									1982
mm rain	162	161	74	62	102	76	64	66	115	20
roof (square meters)	25	25	25	25	25	25	25	25	25	25
yield (liters)	3240	3220	1480	1240	2040	1520	1280	1320	2300	400
# days/month	28	31	30	31	31	30	31	30	31	31
# liters/day consumed	70	70	70	70	70	70	70	70	70	70
amount consumed	1960	2170	2100	2170	2170	2100	2170	2100	2170	2170
yield - consumed	1280	1050	-620	-930	-130	-580	-890	-780	130	-1770
change in tank supply	1280	1050	0	0	0	0	0	0	130	0
month's strart tank (liters)	0	1280	2330	1710	780	650	70	0	0	130
deficit (liters)	0	0	0	0	0	0	820	780	0	1640
overflow (liters)	0	0	0	0	0	0	0	0	0	0
carryover (liters)	1280	2330	1710	780	650	70	0	0	130	0

APPENDIX D
SURVEY RESULTS

	BEQUIA	CANOUAN	MAYREAU	UNION	TOTAL
CONSTRUCTED	10	15	11	15	51
INSPECTED	7	8	11	10	36
SYSTEMS					
TANKS					
*Leaks					
no leaks	2	1	3	2	8
minor leaks	4	3	5	1	13
major leaks	1	4	4	6	15
*Cracks**					
"puddle" apparent	2	4	6	8	20
top/wall seam minor	3	/	3	/	6
top/wall seam major	3	/	2	6	11
base/wall seam minor	1	1	5	4	11
base/wall seam major	/	1	1	1	3
walls minor	4	3	6	1	14
wall major	1	2	4	2	9
top minor	5	/	2	1	8
top major	/	1	1	/	2
*Inlet pipe seal					
tight fit	2	2	/	1	5
fair fit/minor cracks	1	1	1	/	3
poor seal w/ openings	/	/	/	1	1
no designated inlet opening	2	1	3	1	7
*Hatch Cover					
tight fit	1	2	3	/	6
fair fit/minor cracks	1	2	/	1	3
poor fit	4	/	3	2	9
no hatch cover	/	1	/	1	2
*Mosquito netting in place	1	0	0	0	0
GUTTERS & DOWNSPOUTS					
*General condition					
*Gutters					
well supported	3	2	8	5	18
supports missing/sagging	/	3	3	1	7
overflow	1	1	/	1	3

	BEQUIA	CANOUAN	MAYREAU	UNION	TOTAL
*downspouts					
connections poor/sagging	1	1	/	1	3
good condition	2	/	3	5	10
*screening					
screenning in place/good repair	/	/	/	/	0
no screening	4	/	5	3	12
screening in poor repair or inappropriate	1	2	5	3	11
ROOFS					
*covering material (all galvanized metal)					
*condition					
<10% rust	1	1	3	4	9
10-30% rust	1	1	3	1	6
>30% rust	1	4	3	/	8
*setting					
trees overhang	/	1	/	/	1
INTERVIEWS					
SYSTEMS					
TANKS					
*maintenance					
once/year	5	5	5	4	19
once/two years	1	/	/	2	3
once/three years	/	/	/	1	1
never done	1	1	/	/	2
disinfect					
fresh water rinse					
*Leaks repaired					
repairs successful	1	1	1	1	4
repairs unsuccessful	1	/	3	1	4
no repairs	/	/	2	6	8
WATER QUALITY					
*Treatment					
water never treated	/	1	/	1	2
fish treatment	4	3	3	6	16
boil	1	/	/	/	1
chlorine	/	/	1	1	2

	BEQUIA	CANOUAN	MAYREAU	UNION	TOTAL
*Illness					
illness attributed to drinking the cistern water	0	0	0	0	0
QUANTITY					
*Supply					
sufficient for dry season	1	0	1	1	3
need for alternative water source	3	8	10	8	29
share	3	0	1	1	5
tank overflows					
once	1	0	1	1	3
frequently	2	1	3	1	7
never	2	5	2	4	14
SUPPLEMENTARY TANKS					
ferrocement tank	0	1	0	0	1
abandoned/replaced supplementary tank built	0	1	3	2	6

**Major cracks defined as being equal to or wider than 2 mm/minor cracks < 2 mm

Notes:

Spigots: recipient installed spigot; two spigots not working; two dripping; one recipient replaced spigot; one Tank had no spigot, only an outlet pipe.

Two tanks with no overflow pipe; one just had a hole in top of wall, second had no opeing.

Hatch covers: one recipient replaced hatch cover; one self-built hatch cover and inlet.

Leaks: one has just started to leak; holes in wall of one tank

Repairs: one recipient repairs (patches leaks) yearly

Misc.: two recipients with supplementary tanks uses ferrocement water for laundry only; one recipient considering destroying her tank.

VITA

Sheila Salwa Carman was born in Concord Massachusetts where she attended parochial and public schools and graduated from Concord-Carlisle Regional High School. She grew up in West Concord with one sibling, a brother, Peter, and her parents, Catherine Carman and Stanley Salwa. Later in her life she began her undergraduate college studies earning a Bachelor of Science degree from the Geo-Physical Science Department of Fitchburg State College (FSC) in 1993. As an undergraduate at FSC she was active in the "Geo Club" and served as public relations officer and secretary in consecutive years.

Sheila came to the Geography Department at the University of Tennessee, Knoxville in the fall of 1993 to begin her study towards a Masters' degree. The following spring semester Ms. Carman accepted a teaching assistantship with the department. Her degree was awarded in August 1996.

The author has received two grants each from the McClure Foundation for the Study of World Affairs and the Stewart K. McCroskey Memorial Fund for research for this study. She is a member of the Association of American Geographers, Caribbean Studies Association, the Nashua River Watershed Association and the American Rain Water Cistern System Association. She has three grown children scattered around the United States: Trisha in Denver, Sandy in Boston, Jim in Memphis.