A water self-sufficient elementary school for Puerto Rico

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A water self-sufficient elementary school for Puerto Rico

by

Roberto S. Hernandez

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF ARCHITECTURE

Major: Architecture

Major Professor: David A. Block

Iowa State University

Ames, Iowa

2000
Graduate College
Iowa State University

This is to certify that the master's thesis of
Roberto S. Hernandez
has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy
DEDICATION

To
my wife,
Sandra Esther,
and my infant son,
David Alejandro:
your
love
inspires
me!
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Previous to the 1994 drought in Puerto Rico, water rationing was being practiced actively throughout the inland communities. However, soon after the 1994 drought, water rationing became an ongoing problem throughout the entire island. A water collection device, such as a well designed roof and a rainwater storage tank, if employed with a conscientious recycling program, would enhance availability, and can easily address any long-term water-rationing situation. This research focuses on how a public school in Puerto Rico could collect, conserve, and recycle stored water within its structure and perhaps stop the ongoing practice of water rationing in Puerto Rican public schools. To reach this objective, an innovative prototypical school unit must be built. This special design may solve the water crisis in Puerto Rican public schools for good.
INTRODUCTION

Puerto Rico is a beautiful tropical Island in the Caribbean Ocean with a population of almost four million people. The majority of the inhabitants are poor and there are very few natural resources. These resources are basically its flora and fauna, which attract thousands of tourists annually. The average temperature on the Island is 79.1° Fahrenheit, with a relative humidity of 70% during the day. As a major tourist attraction in the Caribbean, Puerto Rico is known for it lush greenery. However, the average yearly rainfall varies regionally.

In 1994, Puerto Rico suffered a severe heat wave followed by a devastating drought that damaged crops, especially coffee, plantain, and pineapple. The drought also depleted the water supply of 1.6 million residents who lived in and around the San Juan area ("Worst" Sec. 1).

A good example of the water predicament faced by Puerto Rican communities is 17 miles south of San Juan, in the municipality of Caguas, which in the summer of 1994 became a drought-stricken town. The Caguenses, mostly poor and lower middle-class residents, did not see a drop of running water from their home faucets for a month and a half. Although the poor inhabitants of Caguas suffered from the water shortage, the children suffered most. They enjoyed neither drinking
water nor running water to bathe themselves. Even worse, they were deprived of a school education for three months, because most public schools in the Caguas region were closed due to extended water rationing. Even though this intense drought and recurring water rationing affected only three months of the Caguas school year, this could turn out to be a year-round problem for most Puerto Rican public schools.

Unlike the private schools in Puerto Rico which may rely on water cisterns, the public schools have installed only small water storage tanks, typically 50-gallon water tanks, that supplies water for all the school's needs (see Figure 1). It appears, however, that the initiatives taken by both the public and private sector, to solve the water rationing in Puerto Rico and its schools, are proving to be inadequate.

In 1995 the island's inhabitants were on the verge of a severe water crisis. Generally, water shortages are common in Puerto Rico throughout the year. Although there is no dry season, for four to five months, generally from January through April, there is a diminished rainfall (Picó, 1974). Rationing of water in the inland regions is common during

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1 This problem in Puerto Rico has led federal and local governments to adopt three drastic measures: 1) rationing water supplies to all homes and schools, 2) denying some homes and/or schools access to water for as long as 24 hours at a time, and 3) constructing a "super aqueduct" between the two major water reservoirs on the island. The private sector recommends purchasing an above-grade water cistern, placing it on the roof of the house or school, filling it up with tap water, and hooking it up to the plumbing.
these periods of diminished water supply. As a result, thousands of families, especially children, suffer.

The severity of the 1994 drought caused the closings of public schools in communities that had no backup water storage systems. Basically most school closings in Puerto Rico occurred during the months of August through October, following the onset of the drought because water supplies were depleted. The normal summer vacation of Puerto Rican school children is during June and July. Thus, students in areas affected by severe drought could have received formal education for only seven months of the year instead of the traditional 10-month school year. However, absenteeism during and following the 1994 drought was greater in communities with poor water contingency plans.
The drought has continued through the beginning months of the 21st century. Most communities have taken some rudimentary measures, such as collecting rainwater in large barrels, for use during periods of rationing, or by sharing latrines. In very poor communities, however, water conservancy is minimal and latrines are uncommon.

After much thought and study of the water-rationing problem in Puerto Rico, especially as it affects young school children, the following research questions emerged: (1) What factors contribute to the need for establishing a new water system for schools in Puerto Rico; and (2) What features in the new water system design meet the water needs of schools in differing regions during periods of water rationing? Because each region in Puerto Rico experiences varying amounts of rainfall and consequential water rationing, there is a need for a long-term solution for public schools that are struggling with this water predicament.

This study incorporated an experimental design of a water conserving school. A content analysis was conducted to study the water situation in different regions in Puerto Rico. Factors considered were annual precipitation levels, and community structure and resources. Data gathering techniques used in the study were based on observation, examination of archival records, interviews, and focus groups. Then the data were analyzed to establish a theoretical basis for designing a
model public school that features a self-sufficient water supply. Thus, a prototypical design could be presented to communities throughout Puerto Rico for possible implementation.

The school, in this researcher's opinion is the cradle of society. Thus, the school is a site where teachers not only teach grammar, math and history to children, they also teach social and moral values. Because water shortages are common throughout Puerto Rico, one important value that should be taught in schools is the value of conserving and recycling potable water.

The main thrust of this research was to propose a design that could solve the water problem for the majority of poor, low, and middle-class public schools in Puerto Rico. The school structure would capture rainwater and store it below grade level for safekeeping against vandalism, disease, and inclement weather. Most important, the school would also become a teaching laboratory for students to study, learn, and understand the importance of water conservation, which is an objective that the current Puerto Rican governor wants to encourage. Such a plan could become a model for other communities, especially developing countries, throughout the world. Therefore, the main purpose of this research was to introduce a design that could be used to solve the water crisis in Puerto Rican public schools permanently.
LITERATURE REVIEW

In 1997, water rationing was ordered, for the second time in three years, in the San Juan area ("Water" 16). The environmentalist David Schwartz pointed out in his 1996 article that "243 million gallons of water per day 'disappear' every day in Puerto Rico" (96). This water disappearance is most likely caused by wasteful practices, leakage, and evaporation. What will happen to the Puerto Rican water supply if water continues to be lost at this rate? What will this do to the public school system in Puerto Rico?

In 1994 Mireya Navarro's article, "Worst Drought in 30 Years Brings Rationing to Half of Puerto Rico," presented troubling accounts of what water rationing can do to poor communities in Puerto Rico. She wrote that "Rural (poor) families have had to relinquish their toilets and have started using a latrine that they share with neighbors" (Sec 1). She also wrote that

Lake Carraizo, the reservoir that supplies water for half of the 1.5 million people who live in the San Juan metropolitan area, has not been dredged since it was built in 1953, and agency officials say it has lost 65% of its capacity to sedimentation. (Sec 1)

However, on an uplifting note, Navarro wrote that "the local Governor, Pedro Rosello is planning an educational campaign on the need to conserve water" (Sec 1).
The following year (1995), Mireya Navarro published a second article entitled, “Taps Go Dry as Puerto Rico Copes with Drought.” She began on a sour note by writing, “Beginning today (Jan. 17, 1995), water for 700,000 residents, mostly in the San Juan area, is being cut off on alternate days, indefinitely” (A10). Navarro described how the local government had adopted three drastic measures to handle the water shortage: 1) ration water supply to all homes, 2) deny some homes access to water for as long as 24 hours at a time, and 3) construct a “superaqueduct” between the two major water reservoirs on the island. However, the superaqueduct initiative was criticized as a short-term solution to a long-term problem (“Tap” A10).

Environmentalist David Schwartz wrote in the winter issue of the Latino Studies Journal that the drought was not the only culprit in Puerto Rico’s water shortage problem. He wrote that:

The worst drought of the century was to blame [for the water shortage], but pollution of underground water sources were also to blame. Many of the aquifers, underground sources of fresh water, are either contaminated by industrial waste or have become salinated. This clearly shows why Puerto Rico has continued to depend more and more on rainfall for its potable water. (95)

He closed by noting that “the water shortage problem extends from polluted ground water to toxic waste disposal and pollution of the waters surrounding the island” (91).
A San Juan reporter, Mary Buckner Powers who writes for the popular science magazine ENR, noted in her 1994 article, "Puerto Rico Faces a Water Crisis" that a "drought, disrepair, and bureaucratic delays have strained the island’s water system to a critical point. While the mountainous terrain... caused heavy sediment flow into the 41-year-old Loiza Carraizo reservoir, it was politics that kept the lake from being properly maintained" (9). She blamed the local government for being ill prepared to handle the water shortage problem that most Puerto Ricans suffered.

Two years later Powers wrote a second article in the same magazine, but this time her opening statement was that "Drinking water should be flowing freely again in San Juan by 1998 as the government prepares this week to remove 6 million cubic meters of silt clogging the city’s major drinking water source" (16). She sounded a bit cautious in the introductory phrase of "Puerto Rico Water Work Flowing," but her views toward the local government sounded more optimistic.

The popular magazine, Utne Reader, called for an immediate action and a multidimensional solution to protect the world’s water supply. The article claimed that "by the middle of the next century, the world population will double... and they will be sharing the same amount of water we have today. As water becomes scarcer, it will become a commodity just like iron or coal" ("Drying" 76). On the other
hand, "The Drying Game" concluded on a savvy note concerning the collection of rainwater to fight the water shortage problem: "Collecting rainwater makes people much more in touch with the weather, the soil, and the importance of water, and makes them better stewards of the land" (79).

In "Drinking Fog," Luis Tricot discovered a small town in Chile of 400 residents that was practicing an environmentally safe way to gather water, that was proving to be a sustainable source of running and drinking water for the whole town. He wrote, "After a 20-year drought, Chungungo has its own supply of drinking water" (47). The water is obtained from thick fogs typical along Chile's northern coastline. The fog is caught in a nearby rain forest by huge nets with water containers at their base. About 1,900 gallons of water are collected each day and then piped into town ("Drinking" 47).

In Free Water for a Thirsty World, L.L. Williams (1990:60) illustrates Chile's "Drinking Fog" method.

In Robert Kourik's "Even During Droughts Cisterns Deliver Rainwater," he noted that "Cisterns are coming back, due to dwindling sources of clean water, erratic supplies during droughts, and a renewed interest in water independence" (44). Kourick's article also presented an environmentally safe way to collect water, by rainfall that can prove to be a staple in places where water rationing is a problem. He listed the surfaces needed for harvesting rainwater into a water storage
container: terra-cotta tiles, stucco, painted metal roofing, untreated wood shingles, and composite shingles. He concluded his cistern findings in two tables. Each table explained to the public how much money could be saved per gallon of water. The bigger the cistern, the more money and water that can be saved. Kourik's table illustrated the positive way to save and to economize water spending (see Figure 2).

Figure 2. Estimating daily and annual rainfall runoff
The research contained in the previous articles was very useful in the formulation of the objectives of this research project. Each article presents the grim truth about what is happening or could happen to the surface water supply in Puerto Rico and the world. Together, these articles support the contention that there is a need to prepare a long-range plan to resolve the water crisis experienced in Puerto Rico today. While most of the articles do not specifically address how water rationing may be affecting the school system in Puerto Rico, it is logical to assume that the school system along with the rest of Puerto Rican society is affected severely by water shortage.
WATER NEEDS IN SCHOOLS

The major professor supervising this research assisted in calculating the total amount of water that would be needed in the school's storage tanks. Even though the proposed school would provide for the needs of its entire staff and students: classrooms, restrooms, hallways, cafeteria, music and art room, and media/library/computer center, its main objective would be to provide running water for all the utilities—restrooms, kitchen, drinking fountains, science lab, etc., throughout the year. The school would be comprised of seven classrooms, from kindergarten to sixth grade. Each classroom could have up to 30 students, which is a typical classroom size in Puerto Rico. According to Ben E. Graves' book, School Ways, this is the maximum number of students that can be housed in a single classroom (72). Thus, the elementary school population would be about 210 students. The typical school staff in Puerto Rico, for a school of this nature, is comprised of the following individuals: a principal, secretary, librarian, custodian, and seven teachers (who will teach all of the school's subjects).

The Time-Saver Standards for Architectural Design Data by John Hancock states that in a school that houses a day cafeteria but no gymnasium and no showers (such as the
elementary school in the proposed model for a school), the average student will use approximately 20 gallon of water per day (198). Multiplying 20 gallons of water per day by 210 students, the water expenditure for a day’s worth of classes would be 4,200 gallon of water. The consumption of water by the staff was not considered because theoretically it would be a fraction of the school’s population; therefore by adding or not adding the staff would not make a difference in water consumption. There are 185 school days in Puerto Rico. Multiplying 185 school class days by 4,200 gallon of spent water per day, the total amount of water needed to supply the school population in a year would be 777,000 gallons of water.

Currently Puerto Rico is experiencing a water cut-off every other day. In 1994, the Puerto Rican government established this measure as a short-term solution to supply the entire island with running water. This practice continues eight years later, in the year 2000.

The elementary school’s water program can be designed to function without outside intervention and without tapping into an existing water source, thus making water consumption in the school a closed system - storing and recycling rainwater. The method of operating this system is quite simple. Instead of building a storage tank that would hold 777,000 gallons of water -- an enormous and expensive task, the proposed system will require only three large-sized (approximately 42,000
gallons each) storage tanks (a rain water storage tank, a water treatment tank and a main storage tank) to address the school's water consumption problem.

The rainwater is first collected on the roof of the building where it is channeled to collection pipes that descend into the building. The students will be able to monitor its flow as it descends through the transparent PVC (polyvinyl chloride) pipes. The collected rainwater then enters the rainwater storage tank, a large tank located on the first floor. This water is used directly to feed the drinking water fountains and the lavatories, etc., of the building. Initially, it will also feed the water closets.

The used water, water from the drinking fountains, water closets and the lavatories, will all go to the water treatment tank. There it will be treated; and when treatment is completed, it will continue to the main storage tank. The water from this tank will be re-used for the water closets and lavatories, again and again, but could also be used for drinking water as well, because the treatment tank will purify it. This type of water treatment tank is readily available in North America, and has been used in the Ames, Iowa, vicinity as well.

When the rainwater storage tank is full or nearly full, this water will be used for drinking and lavatories. However, when it is not at capacity, the main storage tank will provide
that function as well. Since the water treatment tank can purify the water to the extent needed for drinking, a continuous cycle of water usage, then treatment, then re-usage can occur.

By virtue of the above water recycling plan, a small amount of water can meet the school's needs, with only a small additional amount provided by the rain water treatment tank. When there is a large amount of rainfall, then less water will need to be treated for recycling.

It is possible, that the school will not need to be tied into a normal sanitary sewage system, due to its continuous recycling capabilities. This will be a major advantage especially if the school is located in less developed areas of Puerto Rico where good sanitary sewage systems are not available or not dependable.

To address a worst case scenario, the water tanks should be sized according to the 1994 drought's precipitation levels, which was 35% less than the average annual precipitation. (see Figure 3). Assuming that a bad year could produce approximately 40 inches of rain, water captured in a typical manner, by means of a sloping roof that has approximately 8,800 sq. ft., will translate into about 200,000 gallons of collected water. This amount of water (without employing any recycling method) is not enough to provide a year's worth of water consumption. A fraction of the needed amount could be
DROUGHT IN PUERTO RICO

Water Rationing Beginning

With a drought affecting the Caribbean, annual rainfall in Puerto Rico, shown in inches per month, was 35 percent below normal in 1994.

Figure 3. Monthly water rationing in north central Puerto Rico.

captured (two weeks' worth, for example) for distribution, consumption, and recycling, and will be enough.

The following circumstance was considered as an example: 4,200 gallons of water is used in a school day; 75 percent is recycled; and a maximum of approximately seven days' is needed to treat any gray water into drinking water (based on the
Evenflow Water Treatment System™). Thus, instead of using seven days as the evenflow system suggests, the school should run its water treatment process with a factor of safety of ten days to transform any gray and wastewater into tap water. Therefore, what the school would need is storage capacity for two weeks' worth of collected water, instead of storing a year's worth of water. Would two weeks' worth of stored water help alleviate the water rationing that most Puerto Rican public schools are confronting today? If used in a proper manner, the answer is yes.

Two weeks of water needs is approximately 42,000 gallons of water. By sizing the tanks according to this data, each tank would occupy 5,600 cu ft (i.e., a 30-ft by 30-ft area with an eight-foot high ceiling), just like the area occupied by a standard classroom.

As stated previously, the proposed recycling system would function in this manner: the captured rainwater would be stored in the rainwater storage tank, with the capacity to feed the entire school grounds. The gray and wastewater would be captured and rerouted to the school’s water treatment tank.

Once the gray water is treated appropriately it would be stored in the main storage tank. In due time the water in the main storage tank would also cycle through the school’s fresh water system for consumption. Hence, the recycling system is
in operation from the very moment the rainwater is captured (see Figure 4).

After reviewing current research on different precipitation levels across Puerto Rico, three possible precipitation case studies were designed to challenge the

Figure 4. Flow diagram demonstrating the school’s water recycling process
mechanics of the proposed school's water system. A careful evaluation of each scenario could serve to prove how successful the school's water and recycling system might be given the conditions.

The first case scenario addresses continuous rainfall over a long period of time, with the possibility that the rainwater storage tank could reach its capacity and start overflowing. If this scenario should occur, the school should close the valve that allows the intake of more rainwater into the rainwater storage tank and run all its utilities with the continuous rainfall. The school should also take advantage of this circumstance and discharge its entire gray and wastewater directly into the city's sewage system.

The second case scenario deals with a long dry spell with no rain for up to and including five months (i.e., the worst case scenario would be June-October as in the drought of 1994). In this scenario the school should repeatedly use and recycle all the water stored in its main storage tank, which is approximately 42,000 gallons of water (two weeks' worth). While the recycling of gray and wastewater is underway the rainwater storage tank should be ready to store and accumulate at least ten days of rainfall water (approximately 42,000 gallons of water), which would supply the main storage tank with more water if evaporation or any spillage should occur.
The final case scenario confronts the school’s water system with short periods of rain, but not enough to fill [at once] the rainwater storage tank to capacity. If this should happen the rainwater storage tank would gather whatever amount of water it can and immediately supply the school’s utilities with running water (the rain water tank would also be ready to store two weeks’ worth of rainwater). All gray and waste water, produced by the school’s patrons, should be sent quickly to the school’s water treatment tank for adequate processing -- all solids should be disposed into the city’s sewage system. Once the treated water arrives at the main storage tank, both tanks (the rainwater storage tank and the main storage tank) can address the school’s needs simultaneously, if necessary.

All three case studies as presented could be handled adequately by the school’s proposed water recycling system, and by using the school as an active player in the process of capturing any amount of rainwater, the school becoming the key factor in the recycling water process. Furthermore, the school will not only house the storage tanks but will also become an in-house recycling educational laboratory. The children can view the capturing of rainwater through see-through piping, observe how the water is stored in each transparent tank, and become aware of how much water they are
consuming by reading measuring devices posted along the piping and storage tanks.

Therefore, the main goal of this new water system, which is to educate the children about water conservation, would be attained by this proposal. In addition, this year-round water conservancy plan might also help the local government provide water conservation education to the general public. Currently, there is an attempt being made to implement and promote public water conservation throughout the school system and adult community centers in Puerto Rico.
The public school featured in this design will teach the importance of water conservation as a part of its general education curriculum. The children will inherit the benefits of this educational emphasis on water conservation beyond graduation. As an integral part of this water conservancy system, the school will not only serve as an educational facility, but also as a center for speculation, theory, and hands-on water conservation. The proposed school will also be prototypical and adapted to the different climate zones that are present in Puerto Rico.

The building should reflect the respective precipitation zone. Even though Puerto Rico is an island, it has a varied climate. In the northeastern part of Puerto Rico lies the tropical rainforest, El Yunque. With its lush green forest, humidity and rain, it has an annual precipitation of 188 inches. Approximately 150 miles southwest of El Yunque there is a desert-like region known as El Desierto Seco de Guanica, with an annual precipitation of 40 inches of rain. Thus, in the northern, eastern, and western regions of Puerto Rico there is a vast difference in climate, with annual rainfalls of 80 to 188 inches. In addition, in southern Puerto Rico, the annual rainfall can fluctuate from 40 to 60 inches (see Figure 5).
The sites in which the school will be built will vary in climate from region to region and from high to low lands. Although the building could sit in the mountainous or plateau regions in Puerto Rico, what really is driving the design is the annual precipitation.

Assuming there is one classroom for each grade, a school housing students from kindergarten to the sixth grade will need seven classrooms. Every room will need enough space for desks, space for walking and stretching, tables for conducting experiments, and cabinets for storing school supplies. Based on these needs, it is estimated that each classroom for 30 students will need 900 square feet (30 ft x 30 ft).

The school will contain two levels (see Figure 6). The first floor will house the administration department in the
Figure 6. Two story side elevation of proposed design center of the building, a cafeteria and lounge, a music/amphitheater hall behind the cafeteria, a kindergarten, and an enclosed basketball court that is opposite from the music/amphitheater hall (see Figure 7).

Figure 7. First floor plan of the proposed design

The kindergarten room will be on the first floor next to the basketball court so that the children can come and go with ease. By having the enclosed basketball court near the kindergarten, the children can play in security, protected from the elements (see Figure 8). The teachers can remain in
the kindergarten room yet supervise the students' recreation activities.

The enclosed cafeteria space will serve as a multifunction unit. When the cafeteria is not in use for food service, its space will serve a second function as an art shop where the children can paint, draw, and do other creative activities. The first floor is designed for the children to move from floor to floor with ease (see Figure 9). The children will access the second floor through the cafeteria lounge/art shop area.

Figure 8. Children playing next to kindergarten
Figure 9. 1st floor staircase that leads to 2nd floor

The second floor plan will comprise a media/library/computer center and the remaining (1 through 6) classrooms (see Figure 10). The media center, which will be situated directly above the cafeteria lounge, will serve as the passageway for the students to access their classrooms. Once the students arrive on the second floor by way of the cafeteria/lounge, or when it is time to leave for the day, they will pass books, research materials, audio-visual material, and computers. This design enables students to be surrounded by pedagogical materials as they come and go from classrooms.
This school floor plan was observed at Northwood Elementary School in Ames, Iowa, and this researcher believes it to be a sound educational design principal. Too often libraries in Puerto Rico are tucked away in a remote corner that is not easily accessible to the students. A school with this multipurpose plan, featuring a design that promotes instruction and at the same time provides security for its inhabitants, should incorporate strategies that make the most of heavy traffic areas.

The classrooms will be divided into two clusters. One cluster will house grades one through three, and the other cluster will contain grades four through six. The media center will serve as the focal point that connects the two wings. Immediately adjacent to the first through third grade cluster will be an open recreational area where the children can play during their recess time or lunch break.

The second cluster, which will house grades four through six, will feature nooks and small balconies for study and conversation. Both wings will have interior hallways exposed to the open sky. This exposure will accommodate daylighting needs for the classrooms at both ends, and allow the trade winds (which are common in Puerto Rico) to pass through the hallways and cool the interior of the building. It will also resemble an open atrium, adding a Spanish touch to the design.
Large planters and seating devices will be placed along the open hallways (see Figure 11). Resembling atriums, these hallways will serve as gathering spaces for the children to talk and work in small groups while cultivating flowers and vegetables. The openness of the hallways will allow rainwater to fall inside and nourish the plants. The remaining water will be captured and diverted to the storage tanks below. The hallway design may also include an escape valve that will route excess water to a nearby green garden. The climate in Puerto Rico permits such openness.

The rooflines will also serve a multi-purpose function in the design (see Figure 12). Constructed of reinforced concrete, the roof can be sloped to capture all the rainwater
Figure 11. Open hallway with planters and seating
needed to be stored in the storage tanks below, while sheltering the second floor from the elements, such as excessive rainfall, flying debris, and tropical storms or even during hurricanes.

Figure 12. Roofline of proposed design

Due to its structural composition, the roof will be able to modulate temperature swings, allowing the second-floor classrooms to stay cool during the day. For the roof to achieve its main purpose, gathering rainwater and storing it in each tank, reinforced concrete is the material of choice.
DESIGN OF WATER SUPPLY PROPOSAL

Present day architecture in Puerto Rico employs modern standards and reinforced concrete. Puerto Rico's architecture dwells in the limelight of the Modern Movement. Le Corbusier (Trachtenberg & Hyman, 1986), one of the fathers of the Modern Movement which is based on the new technology (i.e., reinforced concrete, p. 487), and that clean designs lead to simplicity ("a purer and more rational and functional architectural environment" p. 488), claimed that his designs are concerned with issues of climate and topography. Many Puerto Rican architects must have followed his example because this type of design has dominated the Puerto Rican skyline (see Figure 13).

Traditional Puerto Rican architectural design is manifested through its colonial Spanish architectural elements. Historic colonial Spanish buildings that are more than 300 years old are still in use in all of Puerto Rico's 76 municipalities. Most Spanish architectural elements are visible in the alcaldia (city hall) and in the towns' squares and churches.

In the Old San Juan area, one is surrounded by rows of colonial Spanish buildings. An enfilade of wrought iron balconies with exposed supports adorns the Old San Juan
Figure 13. Reinforced concrete apartment complex in San Juan, Puerto Rico
scenery (see Figure 14). Classical wall buttresses and friezes are visible throughout the Catholic cathedrals, gubernatorial buildings, apartments, and in the famous San Juan gates. Engaged columns are ever present in homes, shops, and apartment buildings. Louvered shutters, made out of wood, shield proprietors from the spectators' traversing the esplanades below. Although the Old San Juan landscape has an eighteenth century milieu, some modern concrete buildings with superficial plastered colonial Spanish details are visible.

Figure 14. Traditional colonial Spanish architecture with wrought iron balconies and frieze
Aesthetically, in keeping with Puerto Rican culture, it is essential that the proposed school design will make everyone feel at ease. Thus, the design should be reminiscent of local culture, incorporating both modern and traditional Puerto Rican architecture. Therefore, the school design must be a hybrid of the old and "new". The building will be constructed of reinforced concrete because it offers strength and reliability and has the capacity to withstand the vast fluctuations in Puerto Rican weather. By using this material in the design, the school will not only echo the recent success of the local infrastructure, but it can also be molded to resemble the grandeur of traditional colonial architecture, by mean of its plasticity (see Figure 15).

The school is designed as a two-story building. A two-story building (see Figure 16) will enable the children to interact more frequently, and the first floor can stay open to the environment. The second floor will shade the ground floor from the harmful midday sun while protecting it from sudden sporadic rainfall. This design is also more suited to meet the design for exposed water storage tanks that are situated on the ground floor (see Figure 17). Thus, the tanks will be protected from the sun and kept cool by the shade. In addition, the basketball court and amphitheater will be protected from the scorching Puerto Rican sun.
Figure 15. Elementary school design proposed in this research thesis

Figure 16. Section elevation of proposed school design
Figure 17. Floor plan showing water storage tanks located below grade level

Although the second floor will have atrium spaces across the two main hallways, a large overhanging roof will shade most of these passages. Another shading device that will encompass the second floor is the "Miami" window. A "Miami" window is a native Puerto Rican louvered window made out of aluminum sheet metal (see Figure 18). It has a lever in one corner to open or close a group of louvers. This window resembles the traditional Spanish shutter, but instead of opening and closing the window like the shutter from side to side, it is operated manually by its lever. Thus, the operator can open the louvers to a certain degree or close the window shut. The advantage of having a "Miami" window instead of shutters is that it can serve various functions. When open at various angles it can allow daylight to pass through. It can also serve to shade an interior space without the use of curtains, as well as a security device when closed.
Figure 18. A louvered Miami window made of aluminum sheet metal
The roof will be made out of poured concrete. It will slope to the middle, allowing the water to disburse more rapidly and reach the storage tanks. The roof will extend as a curved overhang so it can capture more rainwater. This detail may resemble the exposed cantilevered balcony supports and friezes located on rooftops, which are so popular in the Old San Juan area. To finish the design, wrought iron bars will be incorporated around the open entertainment space and balconies of the school. This last detail adds sentimental value to the design.

The importance of water and water conservancy will be a main feature of the design. The tanks that house the water will be transparent. Measuring symbols will be printed on the tanks to enable the children to read how much stored water will be needed for one week as well as how much water is being consumed throughout the month (see Figure 19). The storage tanks will also be protected from the public by means of a see-through glass box for security reasons. A system of transparent PVC pipes or tubes will crisscross the second floor, and be exposed above the classroom ceilings and the hallways. The ever-present (educational) cargo in the pipes will be rainwater in transit from the roof to the storage tank. These masses of tubing will interlock in a glass column located in the second floor for everyone to observe.
Figure 19. Transparent storage tanks filled with fresh water

glass column will extend to the first floor and the storage
tanks.
PROPOSAL FOR WATER SUPPLY TO SCHOOLS

The grounds for this proposal were based on data gathered through a content analysis that was conducted by this researcher to study the water situation in different regions in Puerto Rico. Two research questions guided the experimental design of the study: (1) What factors contribute to the need for establishing a new water system for schools in Puerto Rico; and (2) What features in the new water system design meet the water needs of schools in differing regions during periods of water rationing? The first question addressed the ambient factors based on the geography of Puerto Rico whereas the second question posited three case scenarios to test the proposed design.

Puerto Rico's ambient factors such as its weather, local building materials, its people, and archival records influenced the decision-making of the design. Most importantly, the Puerto Rican weather is a factor that needed careful consideration in the design. Hurricanes, fluctuating precipitation levels, a scorching sun, and easterly trade winds that blow between 5 and 30 mph are constantly crisscrossing the Island. In addition, the communities' needs were carefully scrutinized to support the experimental design.

As mentioned previously, three case scenarios hypothetically challenged the viability of the design. Each
scenario represented a different challenge threatening the design. An adequate response, as shown earlier, to the three case scenarios could be used to provide proof that the actual construction of the experimental design is feasible.

The ultimate goal is for the design to actually be constructed. For this to occur several issues must first be addressed. As mentioned previously, the dual purpose of this research plan was to serve the instructional needs of the students and the community, while addressing the water-rationing problem that affects the public schools in Puerto Rico. The viable construction of an innovative public school will not only provide shelter and enhance the school’s curriculum, but also serve to collect, store, treat, and recycle rainwater, therefore eliminating the need for water rationing in the school.

Phase one will consist of presenting this proposal, the construction of an elementary school for the purpose of water recycling and address the educational needs of the students and the community, to the executive director of the Puerto Rico Water Company (PRWC), Gerard Mohr, to the senate president, Charlie Rodriguez, who heads a special senate committee on the Aqueduct and Sewer Authority of Puerto Rico, and to Victor Fajardo, who heads the Puerto Rico Department of Education. Both the PRWC and the special committee are currently working on addressing the Puerto Rican water-
rationing problem, but they admit it may take years before the water woes of the Island become a thing of the past. The likelihood of the success of this proposal is imminent due to the simplicity of the design and the dual nature of its purpose.

This is a construction proposal to build a prototype of an elementary public school that will include the school grades of kindergarten to sixth grade (see Figure 20). The school is designed to capture rainwater (by means of its roof) and store it in tanks. The school will also house a water recycling plant that treats and transforms rainwater into potable water. By carrying out this construction/education plan, the school will address and perhaps alleviate the current water-rationing problem that Puerto Ricans are confronting island-wide, especially in the rural zones of the country.

The site proposed is the Caguas Villa Nueva barrio. The proposal must identify a specific site where the school should be built. This research proposes to build a prototypical school that will attract attention nationwide. Caguas Villa Nueva is one of many barrios island-wide that has been affected by water rationing. In some cases, this barrio has gone for as long as one and one-half months without running water. A topographic map of the region
Figure 20. Flow chart depicting the steps needed to achieve construction of the design.
(pinpointing the site upon which the school would be built) would be included at this stage of the proposal.

The following are the reasons for this proposal, how much of an impact (negative or positive) will the project have on the population and/or on the environment? What community will benefit from the project most? Water rationing mostly affects each rural community in Puerto Rico, which is poor and its children attend most of the Island’s public schools. Communities will view this proposal, which is intended to address the needs of the poor population in Puerto Rico, as something beneficial and positive. Less absenteeism will occur with continuous, flowing potable water in the facility. Therefore, the student population may even double in size rather than downsize during the school year, especially under the current siege of water rationing.

On the other hand, a negative aspect for the surrounding environment is the clearing of brush and debris to build the school on a site capable of capturing rainfall. Replacing older trees with new ones on the school’s peripheral grounds could alleviate this impact.

Phase two of this proposal addresses the recycling of water. The type of water recycling technical equipment used in the design and implementation of this proposal is a supplier from which to purchase the equipment.
These are the emergency measures which should be taken if contamination occurs in the recycling process, recommend a maintenance strategy, and identify the party responsible for maintenance. Would the Puerto Rico Water Company take on all the responsibilities, or would there be a contract with a private sector technician? The PRWC has the personnel and equipment to perform necessary repairs and provide emergency service. Since the proposal addresses the public sector, it would be wise to let the PRWC act if problems occur.

The school will run all its utilities efficiently without reliance on an existing water source. Thus, student and faculty/staff absenteeism due to the lack of reliable drinking and running water will be reduced because students will no longer have a reason to stay home. The children will not only learn educational basics, they will also learn firsthand about water conservation and recycling at the school/water laboratory. On the other hand, if the fresh water supply tank becomes contaminated or needs maintenance, by having a secondary fresh water source (the treated water tank), the school can operate for a maximum of two weeks without depending on the contaminated water tank.

This proposal provides Puerto Ricans with an attractive strategy for eliminating water supply problems at public schools. It also serves a dual purpose: to transform Puerto Ricans to consciously conserve water as a way of life.
The proposal will end with a list of possible entrepreneurs who could assume the cost of building the school project. A project of this significance could be supported by the Department of Education of Puerto Rico with federal funding and/or the Gubernatorial Bank of Puerto Rico operated by the Commonwealth of Puerto Rico. Private funding would also be an alternative but would require establishment of a trusteeship.

Once the proposal is completed and submitted to the appropriate people and agencies, there should be little problem in attracting public interest and funds for this project. The benefits outweigh by far any negative concerns. This proposal resolves a recurring water-rationing problem in Puerto Rico by offering a long-term solution to chronic water shortage.
CONCLUSION

This research demonstrated that the capturing, storing, and recycling of rainwater by a school’s breakthrough design could solve the recurring rationing of water in Puerto Rican public schools. Since 1994 Puerto Rico has faced a rationing regimen of water cut-off every other day, especially in its poor rural zones where most public schools are constructed.

The local government in Puerto Rico has implemented what some may call a short-term solution to temporally alleviate the water crisis. A short-term solution that has been implemented is the installation of 50-gallon water tanks on community schools for the removal of solids in waterclosets. Each tank must be refilled with tap water every other day, yet other water needs are not being addressed. The Puerto Rico Water Company acknowledges that it may take years for the water woe to disappear islandwide. The local governor admits that no education on water conservation has ever been implemented at any level. He is seriously thinking about taking the lead in designing a water conservation program for the Puerto Rican population.

Generally, what this research has uncovered is that the current strategies are not adequate. Rural zones across Puerto Rico are not benefiting from these short-term water solutions. Too much time and money are being spent in
frivolous enterprises. In 20 years, if current conditions continue, Puerto Rico may not have any remaining surface water upon which to draw. It is apparent that something needs to be done quickly to resolve this water crisis. In fact, there is an immediate need to resolve the problem now so that Puerto Ricans can reap the benefits for the next hundred years. If the water-rationing problem is not resolved, a bleak future may become inevitable to Puerto Rican’s largely poor communities.

In order to mitigate the future water crisis in Puerto Rico, a design was developed to alleviate the water problem for the majority of poor, low, and middle-class public schools in Puerto Rico. This design is a school unit that will allow for the collection of rainwater by means of its innovative structure. The method of capturing rainwater and storing it below the school will lead to a quick, reasonable and permanent solution for the water rationing problem that all public schools in Puerto Rico face. This water design will ensure a safe and permanent water supply for the school’s students, staff, and utilities. The goal is for the water capturing school unit to become the prototypical school across Puerto Rico. Eventually it could also address the worldwide water shortage expected in the 21st century (“Drying” 74).

This research design could achieve a permanent solution to the rationing of water in Puerto Rico. The water storing
school with its water recycling system could be the answer that Puerto Rico is seeking. Similar techniques are being applied in other countries with good results. By constructing this design, the poor children of Puerto Rico will benefit and also the community. While the children are in school, the community will not have to worry about getting potable water for them. Their children's education will not suffer because there is no running water in the community or in the school. Furthermore, the school itself will be a water laboratory using hands-on techniques to teach the importance of conserving and recycling water. The children will then pass these values to their parents and siblings.
REFERENCES


ACKNOWLEDGEMENTS

It is only through the love of Jesus Christ and support of my family that I have been able to reach this point in my educational endeavor. I extend a sincere thank you... to my wife, Sandra, who encouraged me to leave my place of birth (San Juan, Puerto Rico) and travel almost 3,000 miles to become an ISU architecture graduate student. I would not have been able to finish this enterprise if it wasn’t for her support, faith in me, love, and understanding. To my son, David, and daughter, Franchesca, who do not yet understand or do not know the real meaning behind my research. I used them as my inspiration so that I may be able to build a better tomorrow for their educational future.

I would also like to thank my graduate committee: David Block, John Maves and Joanna Courteau, for believing in me, for their vision, their expertise and encouragement.

I am grateful to my editor, Pat Hahn, for her diligence in the preparation of the written portion of this thesis.

Finally, and most importantly, to my Lord Jesus Christ, thank you for giving me the talent and endurance to reach this far. I offer this achievement to all the children of Puerto Rico, who I hope will soon benefit from this innovative school design.