VIRGINIA WATER RESOURCES RESEARCH CENTER

Water Use and Sustainability in La Altagracia, Dominican Republic

By

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VWRRC Special Report No. SR49-2010

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
BLACKSBURG, VIRGINIA

June 2010

Acknowledgments

This study was supported by the National Science Foundation Research Experiences for Undergraduates (NSF REU) program Grant No.0649070, the Virginia Water Resources Research Center, and the Center for Undergraduate Excellence at Virginia Tech through the Undergraduate Diversity Grant. Mr. Jake Keel at Punta Cana Foundation, Dominican Republic, provided significant help to complete this project. Acknowledgments are also due to Virginia Tech students who participated in the study abroad program during summers of 2008 and 2009.

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Summary

The island nation of the Dominican Republic builds much of its economy on the tourism sector throughout the northern and eastern coastlines. The need to preserve natural resources and study the impact of water demand in coastal areas is crucial to tourism economy and social welfare in the Dominican Republic. While tourism industry for this island nation is booming, availability of adequate water resources are now coming into question. There is a significant need for developing water supply management plans and accountability for water use or water consumption. The major goal of this research report is to evaluate the status of water availability and quality in the eastern region of the province of La Altagracia, specifically in Punta Cana resort area and nearby town of Veron. A secondary goal is to evaluate the feasibility of rainwater harvesting as an alternative water source that will complement traditional centralized and groundwater supplies in Punta Cana resort area.

Findings of this research show that identifying the different community needs throughout the region is the first step towards building a sustainable water future. Implementing rainwater harvesting technology in Punta Cana area shows promise for water conservation. Technological solutions for the region include employing reverse osmosis technology for converting salt water to potable water. Future research needs include investigating of the potential for using other appropriate technologies for water sources development and conservation and a detailed investigation of salt water intrusion in coastal aquifers due to increased population and development.

Key Words: water sustainability, salt water intrusion, water conservation, rainwater harvesting, tourism, Dominican Republic

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1. Introduction

Water is crucial to the existence and success of human populations. It is often the limiting resource in a particular settlement and some believe that freshwater will be the first resource to become widely unavailable (Furumai 2008). With a human population that is continuing to explode, the management of water resources will become of vital importance. The human population is expected to grow nearly 30% over the next 44 years from 6.7 billion people to 9.2 billion by 2050 (U.S. Census Bureau 2009). Most of this growth will happen in developing countries. In order to accommodate more growth, resource management, especially of freshwater supplies, will need to be included in future development plans.

The Dominican Republic is no exception from increasing water demands and limited freshwater resources. The province of La Altagracia in the eastern-most region of the island nation has seen significant growth throughout recent years. Tourism continues to boom and brings significant economic growth to the area and to the entire country of the Dominican Republic. Because of tourism and the increase in available jobs, there has been a growth of local populations in the form of many “shanty-towns,” most which lack basic infrastructure and have unknown population rates. The majority of the water use throughout this region relies heavily on groundwater aquifers with some water coming from surface water in the mountainous regions of this province. If water consumption is not monitored or factored into policy and development throughout this region, saltwater intrusion and contamination of freshwater aquifers in the region could become a very realistic problem in the near future.

The goal of this research report is to evaluate the status of water availability and quality in the eastern region of the province of La Altagracia and investigate opportunities for water conservation. The study area includes three resort areas: the Cap Cana Resort area, the Bavaro Resort area, and the Punta Cana resort area, and the town of Veron. Specific objectives of study include:

(a) Investigate the water quality of the region
(b) Investigate the opportunity for implementing water conservation techniques
(c) Propose methods for continuing water management and planning

The study approach consisted of 1) review of current literature regarding water resources in the Dominican Republic; 2) evaluation of the efficiency and potential for water conservation by implementing rainwater harvesting; 3) design of a rainwater harvesting system for a selected site; and 4) evaluating future water management measures for the region.

2. Literature Review

2.1 Dominican Republic Water Resources

The Dominican Republic boasts 1,288 km of coastline stretching north, east, and south around the country (Factbook 2009). The freshwater withdrawal in the country is estimated at 3.81 m^3/year per capita and has significantly increased over the past decade due to growing economy (Factbook 2009). Because of the significant yearly rain and existence of several large bodies of surface water, the Dominican Republic may seem to have ample water resources. However, throughout the country, there are many general water resource issues. In 2001, a comprehensive environmental assessment study analyzed the status of water resources across the Dominican Republic. This report, prepared for the USAID in Santo Domingo, stated that surface and groundwater salinization was the number one concern throughout the country, especially in the coastal areas (International Resources Group 2001). Additionally, the total water use efficiency throughout the country was estimated at the extremely low rate of 18-25% (International Resources Group 2001). The report recommended conducting more water quality studies and highlighted the lack of a national governmental policy about management of water resources.

The province of La Altagracia is the easternmost province of the Dominican Republic. This province includes the three large tourist areas of Bavaro, Punta Cana, and Cap Cana as well as Isla Saona, a small island off the south coast, among other inland, cities, villages, and towns. The geology of the area is predominately quaternary reef limestone which is highly permeable (Harlan et al. 2002). This rock type allows for quick infiltration of the surface water to below ground freshwater aquifers. The estimated groundwater recharge rate is 300-400 MCM/year throughout the region (Gilboa 1980). Most aquifers in the region contain ample water and can be found at depths ranging from 5 to 25 meters in the low-lying areas and between 100-200 meters in the mountainous areas (Harlan et al. 2002). The groundwater throughout the region is of high quality and high hardness with the exception of the coastal areas such as Punta Cana and Bavaro where most of the groundwater is considered brackish or completely saline (Harlan et al. 2002).

2.2 Tourism Economy and Water Use

Throughout the history of the Dominican Republic, agriculture has been the primary economic industry in the country. Over the past two decades however, agriculture has seen a steady decline while tourism has seen an exponential growth. The Dominican Republic now employs over 772,000 people in the tourism industry which is more than any other country in the Caribbean including Cuba, the Bahamas and Jamaica (World Travel and Tourism Council 2004). Puerto Plata, a region on the northern coast of the island, originally experienced tourism growth in the 1970s and 1980s, before much of the remainder of the country. Unfortunately, Puerto Plata area tourism has declined drastically as a "direct result of environmental degradation" (Foundation for Environmental Security and Sustainability 2004). Contrary to the decline of tourism in the Puerto Plata area, the eastern region of the country has seen constant growth over the past decade. The three regions in La Altagracia which include the majority of the tourism are Punta Cana, Bavaro, and the new development in Cap Cana. This new development includes 18,000 additional hotel rooms which increases the total number of hotel rooms in the country by 30% from 60,394 to 78,394 (Environmental Security and Sustainability 2004). This development is the largest increase in new resorts at one time.

Water use throughout the tourism sector is varied by region, province, and by each particular resort. The policies regarding water use by resorts are lacking and very lenient. The Secretariat of Environment and Natural Resources (SEMARN) was formed in 2000 after the passage of an environmental framework law. This law was a great start in establishing very basic principles regarding issues such as the penalty for polluting and effluent limits (Werbrouck 2004). This new body of decision makers also mandated that every new hotel should include a wastewater treatment plant (Werbrouck 2004). Unfortunately, the environmental legislative body has not yet addressed any regulations on water consumption. It is speculated that the water overconsumption has already caused saltwater intrusion reaching 20 to 50 km inland from the shoreline of the Dominican Republic (Werbrouck 2004).

While environmental degradation is beginning to be addressed at both the national and the individual level, water resources management needs to be immediately incorporated into the decision making process for the tourism sector in order to make further development sustainable (Werbrouck 2004).

2.3 Appropriate and Adequate Technology

Water storage and capture technologies have been used throughout human civilization. Levels of technology range greatly throughout various communities and countries throughout the world. Technology for water storage can include simple things such as catching rainwater in a simple pit or developing a reverse osmosis water treatment plant for desalination. The term "appropriate technology" was first coined by the author of the book *Small is Beautiful***,** E.F. Schumacher (Murphy et al. 2009).

This term, "appropriate technology", has been a topic of debate for many decades. It often refers to the application of technology in developing countries (Practical Action 2007). When the term was first coined, it was often used the same was as "intermediate technology" which is somewhere between traditional village techniques and developed western technologies (Rohwedder 1987). Now it is often referenced as a small scale, low capital investment technology that requires limited technical knowledge to maintain (Murphy et al. 2009). Additionally, as the term for appropriate technology continues to evolve, many believe that this philosophy must also include an environmental and community component to planning (Murphy et al. 2009). Appropriate technology has been criticized as to the effectiveness of the philosophy to significantly impact the developing world (Murphy et al. 2009).

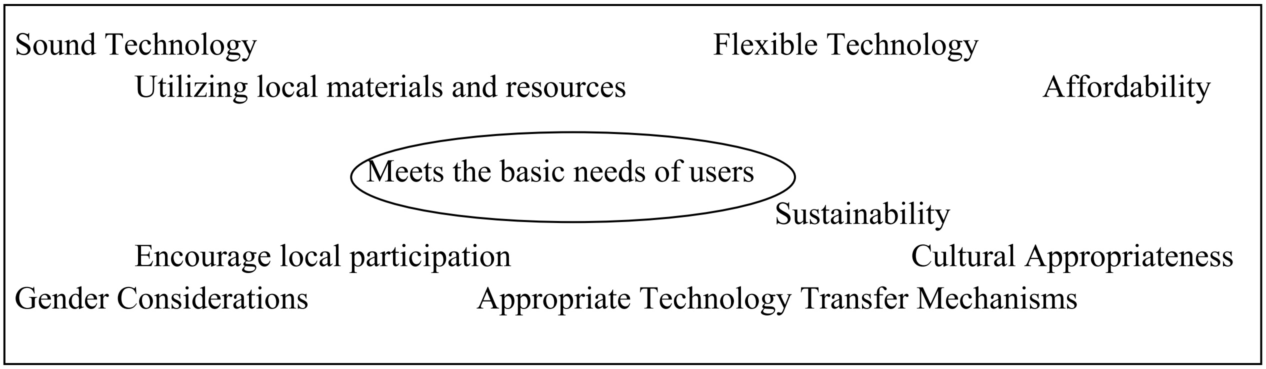

Figure 1. Components of Appropriate Technology (Developed from Murphy et al. 2009)

For this report, the term appropriate technology constitutes of a philosophy that considers many aspects of water development and planning. As shown in Figure 1, while meeting the needs of the users is the most obvious component of water technology, there are many other components that factor into the decision making process for water resource planning.

Appropriate technology as it relates to water and sanitation needs to go above and beyond the limits of designing a technological solution and incorporate "soft aspects of the innovation process" (Murphy et al. 2009). These "soft aspects" of water system design include things such as understanding how water issues must be approached, realizing that there are a variety of circumstances and every community is unique, and identifying the interconnectivity of water issues (Murphy et al. 2009). Additionally, for successful water system designs, every level of society must be held responsible for water use and misuse as well as water system design, implementation, and future work.

2.4 *Rainwater Harvesting Technology*

In ancient times, rainwater harvesting was achieved using channels and diversion systems (Boers and Asher 1981). Some agricultural systems still continue to utilize ancient techniques. Modern rainwater harvesting systems for domestic consumption most often utilizes rooftop collection. The basic components for a rainwater harvesting system include roof or catchment area, and a gutter system which allows water to flow by gravity to a storage tank. In addition to the basic components filters and pumps can be included in design according to the needs of the particular site. The efficiency of a particular rooftop rainwater harvesting system is affected by several factors but the most common efficiency markers are the roof inclination and material and the first flush filter system (LaBranche 2009). Rainwater systems are extremely adaptable according to the needs of a particular site.

3. Study Site

The province of La Altagracia (Figure 2) consists mainly of coastal ecosystems. The northern and eastern coast of La Altagracia boarders the Atlantic Ocean while the southern coast of the province boarders the Caribbean Sea. Three of the ten principal coral reef areas in the Dominican Republic are located in La Altagracia (International Resources Group 2001). Similar to other coastal communities, this region has experienced fishery exploitation due to bottom-fishing techniques (International Resources Group 2001).

Figure 2. Map of the Dominican Republic and the Province of La Altagracia (Public Domain)

The impact of tourism on water resources has not been extensively measured. However, the comprehensive environmental analysis for the Dominican Republic completed in 2001 cited several environmental issues associated with the increase in coastal tourism development. These issues include increased discharge of sediment and wastewater into coastal waters, alternation of natural geomorphic processes due to construction of hotel infrastructure, and degradation of beach and wetland habitat for sensitive species such as sea turtles and waterfowl (International Resources Group 2001). Figure 3 shows the three main resort areas within the provinces of La Altagracia; Punta Cana, Bavaro, and Cap Cana. Also shown is Town of Veron.

Location of Resort Areas:

Red: Bavaro
Green: Punta Cana
Purple: Cap Cana
Blue: Veron

Figure 3. Location of Resort Areas

3.1 *Veron: Water is Life*

The town of Veron has boomed from nothing in recent years. It has grown in response to the continued increase in tourism throughout the region and demand for transient laborers. It is estimated that there are between 8,000 and 10,000 inhabitants in Veron (White 2009). However, estimates within the community speculate that there are nearly 40,000 residents who move in and out of the community annually. The large majority of residents are employed by some aspect of the tourism sector. Employment opportunities include construction labor, taxi and bus services, and various resort jobs.

Water is a precious commodity in Veron. Most of the residents, parallel to the national behavior, drink bottled water to avoid sickness. In the Dominican Republic 67% of the population in urban areas utilize bottled water as their primary drinking water source (National Geographic 2010). The water and sanitation infrastructure in Veron is largely lacking. There is a lack of federal funding for infrastructure because of the unknown number of citizens living in Veron. In order to have piped water to a house, the resident must be able to either afford to drill a well, which is virtually impossible, or must pay a neighbor who has a well. Figure 3 shows a typical water system in Veron.

Figure 4. Piping Systems in Veron

Trash can be seen in piles all over the community. Residents have no faith in the local government collecting trash and therefore dispose of it in any way they please (Figure 5). Because of the transitive nature of this community, it is suggested that the water contamination and pollution are due to the lack of community care.

Figure 5. Trash in Veron

3.2. Punta Cana: Water is Recreation

Punta Cana is located on the furthest eastern portion of the island of Hispanola in the province of La Altagracia. The land was originally home to an indigenous group known as the Tainos. However, Punta Cana as it is known today has a very short history that started in the 1970's. Punta Cana has only recently emerged as a prime tourist destination in the Caribbean. The land in this area was first purchased in the late 1960's and by the early to mid-70's, the first resort was built. This resort was a modest resort with accommodations for around 40 individuals. In 1978 the original Punta Cana Club was joined by Club Mediterranean, which began to build a 350-room hotel in the area. Since that time, further investment in the tourism industry has occurred. The area referred to as the Punta Cana area also includes the resort developments in Bavaro and Cap Cana. Cap Cana is the largest new resort area in the country. This resort development alone will increase the number of hotel rooms in the country by 29.3% (Foundation for Environmental Security and Sustainability 2004).

The water resources of this area are being consumed at alarming rates. If a resort has the money to invest in a well, that resort can consume water at any rate. Since all of the resorts have many wells, water withdrawals are causing salt water to intrude into the coastal freshwater aquifer. An evaluation of the water quality regarding salt intrusion is included in a later section of this paper. As shown through the striking images of Punta Cana (Figure 6), in the tourism region, water is utilized for recreation in stark contrast to the necessity of water in Veron.

Figure 6. Water as Recreation

Additionally, because of the lack of environmental regulations, resort areas have the ability to contaminate the local water ecosystems. In Bavaro, a major environmental concern is the continual filling of wetland and estuaries (Figure 7).

Figure 7. Ecologically Sensitive Areas (Photo credit: Monica Licher 2008)

As discussed earlier, the nearby town of Veron grew as individuals and families moved to the area in search of jobs and to provide a labor force for the tourism industry. An absence of planning and resources has left the area subject to poverty. As shown through the photos of Veron and Punta Cana, there is a stark difference in the use and perception of water. However, the similarity and common ground between Veron and Punta Cana lies in the need to preserve their common water resources for the future. If water resources are not preserved, this resort area will eventually collapse which would be economically disastrous for the local community, the region and the entire Dominican Republic. Therefore, it is critical that a plan for sustainability of water resources be developed and adopted by various stakeholders throughout the region.

4. Plans for Water Sustainability

Water quality is becoming more of an issue throughout the region of Punta Cana and Veron. In Veron, two years of water quality sampling data showed the presence of bacterial contamination in some samples while others seemed to be in good quality. Additionally, during the two years period, water samples from the freshwater lagoons of Punta Cana were measured for conductivity to determine potential increase in water salinity in the area. If salt water completely infiltrates the freshwater aquifer, the cost of purifying water will greatly rise with the increased energy requirement for reverse osmosis technology, common water treatment method for desalination. Additionally, if the groundwater in Veron becomes completely saline, it will be virtually impossible to purify water at a reasonable cost and will force residence to continue their dependence on bottled water.

Figure 8 shows that the conductivity in every freshwater lagoon in Punta Cana increased within the one year sampling time frame. While this is not an extensive data set, it is the first step in providing an adequate sample data regarding the looming problems associated with salt water intrusion.

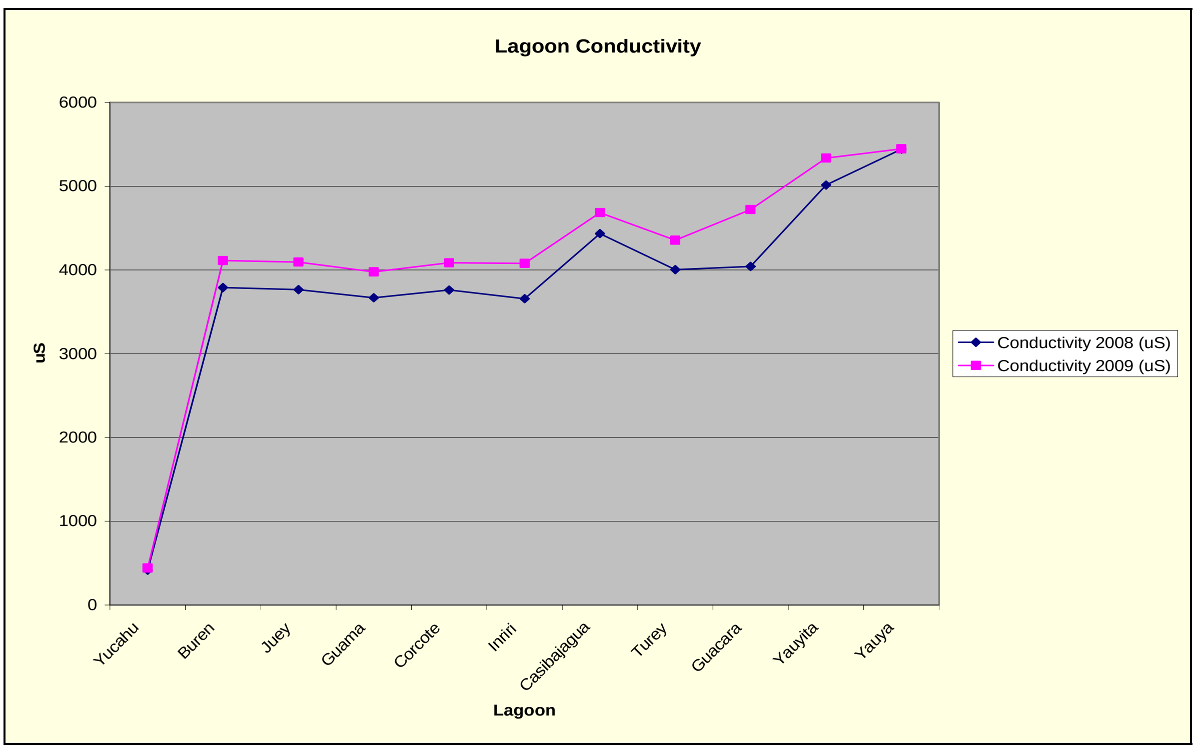

Figure 8. Conductivity Trend of Freshwater Lagoons in Punta Cana (2008 – 2009)

In sampling Veron household waters in 2008 (Figure 9), E.coli contamination was found in no particular pattern throughout different locations in the town. There was a pattern associated with conductivity and total dissolved solids, however. This pattern showed a trend associating higher conductivity and total dissolved solids in areas closer to Punta Cana, and the coast. Since E.coli contamination was not shown in a distinctive pattern, it is uncertain but can be speculated that E. coli contamination may be occurring due to lack of sanitary sewers and underground infiltration of contaminated water and/or water sample contamination after water sample is collected.

Figure 9. Household Water Sampling in Veron

(GIS map courtesy of Dr. Korine Kolivras)

4.1 *Technology and the Environment: approaching the problem*

There is a significant difference between water quality concerns in Punta Cana and Veron and how to address those concerns. More advanced technologies may be employed in Punta Cana with the funding available from resort areas, however these technologies would not be affordable or well received in Veron. This is where the question of appropriate technologies must be evaluated. In order to approach this problem, a connection between technology and the environment must be evaluated. These issues are depicted in Figure 10.

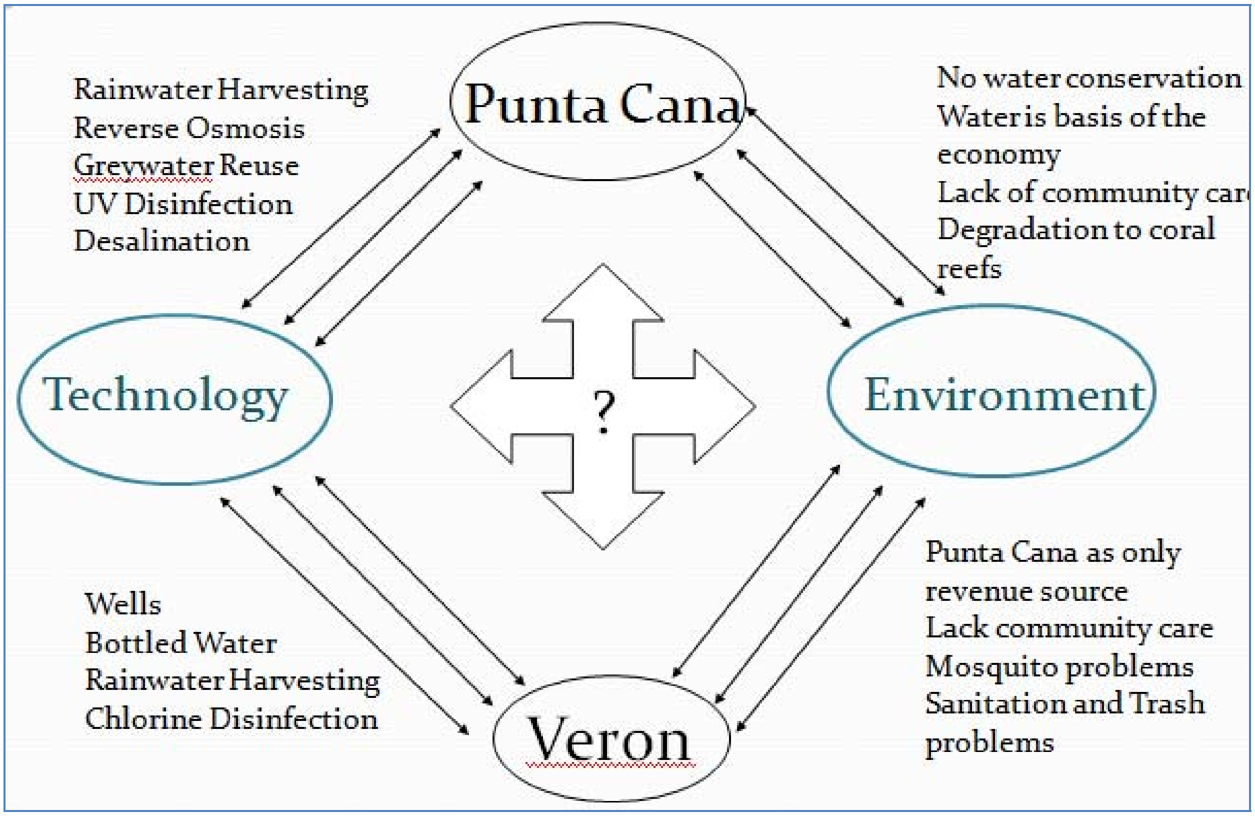

Figure 10. The Environment and Technology Interaction Diagram

First, it is proposed that the water quality issues must be prioritized. The following water quality issues are ranked in priority of concern:

1. Salt water intrusion
2. Reef degradation and wetland preservation
3. Water quality in Veron
4. Long term community care

The reason for saltwater intrusion and reef and wetland preservation being the top two concerns is because these issues profoundly impact the region suitability as a tourist destination. The tourism industry could very easily move out of the area if water is not available and/or the environment is too degraded. Additionally, it is believed that proof of saltwater intrusion could contribute to convincing resort areas to become more sustainable in the future.

The third issue is addressing the water quality in Veron. Although this affects human health and should be viewed as a major concern, the reason it is not ranked above salt water intrusion and reef degradation is because of the current education of the community. As previously stated, many people in the community are aware that bottled water is cleaner than piped water. Many adults and children alike buy bottled water regularly. Part of this use could also be based on a personal preference of consuming cold beverages instead of warm hot beverages. When surveying in Veron, several people explained this desire to consume cold beverages which increases the use of bottled water and bottled soda. A limited water health education program has been conducted in the area through the Virginia Tech Geography Department. Finally, long term community care is necessary for the sustainability of this area. In Veron, because of the transient nature of this community, people do not feel connected to their home. In Punta Cana, the tourists who visit are not connected to the habitat in any way and feel no remorse for the water over-consumption and pollution of the resorts.

The issues surrounding appropriate technological solutions for these problems are many. The first solution available to a region with little fresh water and an immense amount of salt water is to employ reverse osmosis water treatment technologies (Keel 2008). A reverse osmosis (RO) treatment plant has the ability to concert sea water into potable clean fresh water. Desalination treatment plants however have concerns including high energy demand, environmental impact, and disposal salt-residue waste (Younos 2005; Younos and Tulou 2005). The electricity costs of a standard desalination plant costs between one third and one half of the total operating costs (Carter 2009). In addition, with the continual increase of the cost of energy, this financial burden will most certainly grow. The costs of desalination may be economically reasonable to employ for a resort but the cost is highly prohibitive for residents of Veron. Additionally, the impact of water intake to marine ecosystems is largely unknown (Carter 2009). Since the marine ecosystems draw much of the tourism through scuba diving, snorking, and other beach activities, it would be unwise for resorts to invest in a technology with unknown environmental repercussions. Furthermore, the excess saline solution (salt-residue from RO process) is difficult to dispose of after the desalination process (Younos 2005; Carter 2009). Although desalination may be a component of water resources in the future, it is important to analyze the impacts of this technology before relying on it as the sole solution to the emerging saltwater problem. Since the marine ecosystems draw much of the tourism through scuba diving, snorking, and other beach activities, it would be unwise for resorts to invest in a technology with unknown environmental repercussions.

4.2 *The Case for Rainwater Harvesting*

A case study which evaluated the opportunity to employ rainwater harvesting as a water conservation measure on the Punta Cana Resort (Ecological Foundation building) was completed in August of 2009. This study proved that rainwater harvesting could provide adequate amount of water for the PuntaCana Ecological Foundation. Rainwater harvesting could supplement groundwater withdrawals by providing an alternate source of water. It could also reduce the energy used in transporting water because rainwater harvesting is a decentralized water system.

Methods
In order to design the rainwater harvesting system for the PuntaCana Ecological Foundation climate data as well as data regarding the building design and use were collected. This data was then analyzed to produce information regarding potential harvestable rainfall as well as information regarding water use within the main Ecological Foundation Building. From this data, system components were outlined and constructed into a form readable for possible future contractors.

Rainwater Availability
Based on the roof size and the rainfall data, the harvestable potential was evaluated by multiplying the roof size, the rainfall, the efficiency coefficient and a coefficient for unit conversion. Table 3 shows each building's potential harvestable rainwater (m^3) and total volume available for possible rainwater reuse.

The total amount of harvestable rainwater shows the feasibility of the rainwater harvesting based on water use. This information also helps decide the size of the rainwater harvesting system components, especially the storage tank. For this study, monthly rainwater data was obtained through records kept by the PuntaCana Ecological Foundation (Kheel 2008).

The amount water use for the Ecological Foundation is not specifically known. Available information is only an estimate of water usage. Water use for the entire area (Biodiversity Center, gardens, office, and bathrooms of the gardens) is estimated between $33m^3$/day and $80m^3$/day (Kheel 2009). At this rate of water consumption, the potential harvestable rainfall is not nearly enough to provide for all water needs. Based on available information, it is assumed that the majority of the water use is attributed to the garden and irrigation system. Also, a leak in the water storage tank throughout the three months prior to this study skewed the given estimate of water usage.

For design purposes, an evaluation of estimate water usage for the Ecological Foundation Building was constructed based on general water use per person guidelines from the United States Geological Survey (USGS). These estimates give a general guideline for water use of the Ecological Foundation Building (Table 4). As shown in Table 4, nearly 90% of the total water demand could be obtained through the use of rainwater. If the rainwater was only used for non-potable water use i.e. toilet flushing, irrigation, clothes washing, vehicle washing, the rainwater could provide all indoor use and some irrigation demand. Water quality and plumbing would have to be explored further in order to decide the ability of the water to be used for all water uses, potable and non-potable.

Table 3. Harvestable Rainwater Potential in m^3

	Ecological Foundation Building	Environmental Management Building	Storage Building	Gardener Bathrooms	ALL BUILDINGS
Jan	49.8	9.5	5.4	5.8	70.5
Feb	25.2	9.7	2.9	3.8	41.7
Mar	56.7	23.8	5.9	8.5	94.9
Apr	45.3	11.0	5.6	5.9	67.8
May	25.4	8.9	2.9	3.7	40.9
Jun	80.6	18.5	8.8	9.9	117.8
Jul	24.9	6.3	3.1	3.3	37.5
Aug	58.9	11.2	6.6	6.9	83.5
Sep	121.3	33.9	27.0	20.8	203.1
Oct	98.2	33.9	10.4	13.7	156.2
Nov	57.9	20.2	6.2	8.1	92.5
Dec	67.5	24.4	7.8	9.8	109.5
Total	715	211.4	92.8	100.0	1115.8

Table 4. Water Use Estimate for Ecological Foundation Building in m^3

Design Information		
Roof area	**672**	square meters,
Annual rainfall	**133.1**	centimeters
Annual rain harvest	**715,546**	Liters (including .8 efficiency coefficient)
	715	m^3
Water Use		
A washing cycle (50 liters assumed)	**8**	washing cycles per day (2 washing machines, 2 meals of dishes 4 wash cycles in Lab
Toilets (10 liters assume)	**93**	flushes per day (11 employees/12.2 residents, 3 flush/5 flush day)
Shower use (8L/min assumed)	**915**	liters per day (12.2 people daily, 1 shower each)
Total daily use	**2,245**	liters per day
Year use	**819,425**	liters across the year
Will rainwater provide more than 75% of all water use?	**yes**	Rain can provide 87%

System Components

The capital investments involved in implementing this rainwater harvesting system include several components. In addition, a filtration system would need to be included in the design if the rainwater is to be used for potable uses. The single largest and most expensive part of the capital costs is the storage tank. Storage tanks are available in all shapes, sizes, and prices. Because of available supplies and need for a belowground tank, constructing a concrete tank is the most logical for this study site. A number of local construction companies could pour concrete to construct the necessary storage tank.

The other system components include; first flush filters, intake filter, water pump, and new pipelines to connect the current downspouts to the water storage tank. The first flush filters allow the system to function more efficiently by removing debris and organic matter through gravity and a vortex motion. The brand recommended for this project is the WISY filters made in Germany (LaBranche 2009). Also recommended from the WISY Company is the intake filter which allows for the cleanest water to be used when drawing water from the tank. This filter rests just below the tank surface and intakes the best water to be used. Various water pumps can suffice in order to redistribute the water within the building. Because of the height and distance from water tank to distribution, the system would require a 1HP pump. Pumps, depending on availability and company, can range in price.

Cost Analysis

Rainwater harvesting systems are relatively inexpensive in comparison to other systems of water, for example well drilling. They do however require a large capital cost. Operation and maintenance costs are very marginal and depend on the type of components with each system. Cost estimates for various components shown in Table 5 are obtained from the Virginia and Texas rainwater harvesting manuals and may be different based on supplies as well as labor.

The storage tank is the most expensive component with a concrete tank costing between \$0.30- and \$1.25/gallon USD. This tank would, if cost was averaged at \$0.77 would cost \$5400 USD. Required new pipe length to move the water from the downspouts is estimated to be 120m. These pipes are estimated at \$0.30/ft or \$1.00/meter so the cost of new pipes would total \$120USD. The water pump on the current system may be used to pump the water into the building however, if a new pump is required, a Grundfos MQ Water Supply System would cost between \$385-600 USD. The two WWF 150 Filters from WISY are priced at \$1050 USD plus shipping. The 2” coarse floating filter with 7’ of hose is \$320 USD.

Table 5. Cost Estimate

Components	Size	Cost Estimation
Storage Tank	$27m^3$	\$5,400 USD
Pipes	120m	\$120 USD
Water Pump	1hp	\$500 USD
First Flush Filters	2 WWF150 filters	\$1,050 USD
Intake Filter	1 2”filter	\$320 USD
Total Cost		\$7390 USD

A notable difference in the cost will also be the availability of these supplies in the Dominican Republic. While labor and simple construction such as the concrete tank will most likely cost less than those in the United States, the components from the WISY company would cost more because of the need to import them from Germany or the United States (LaBranche 2009). Also, it is estimated that the excavation and implementation of the tank below ground will roughly double the cost of the system costing nearly \$7,000 USD (LaBranche 2009).

Design Sketch

The design components for the proposed rainwater harvesting system were sketched in order to provide a future contractor with a design idea. This design involves new plumbing fixtures at the end of each of the six downspouts on the building. It also involves new plumbing to drain downward into a storage tank with a capacity to hold $27m^3$ of water.

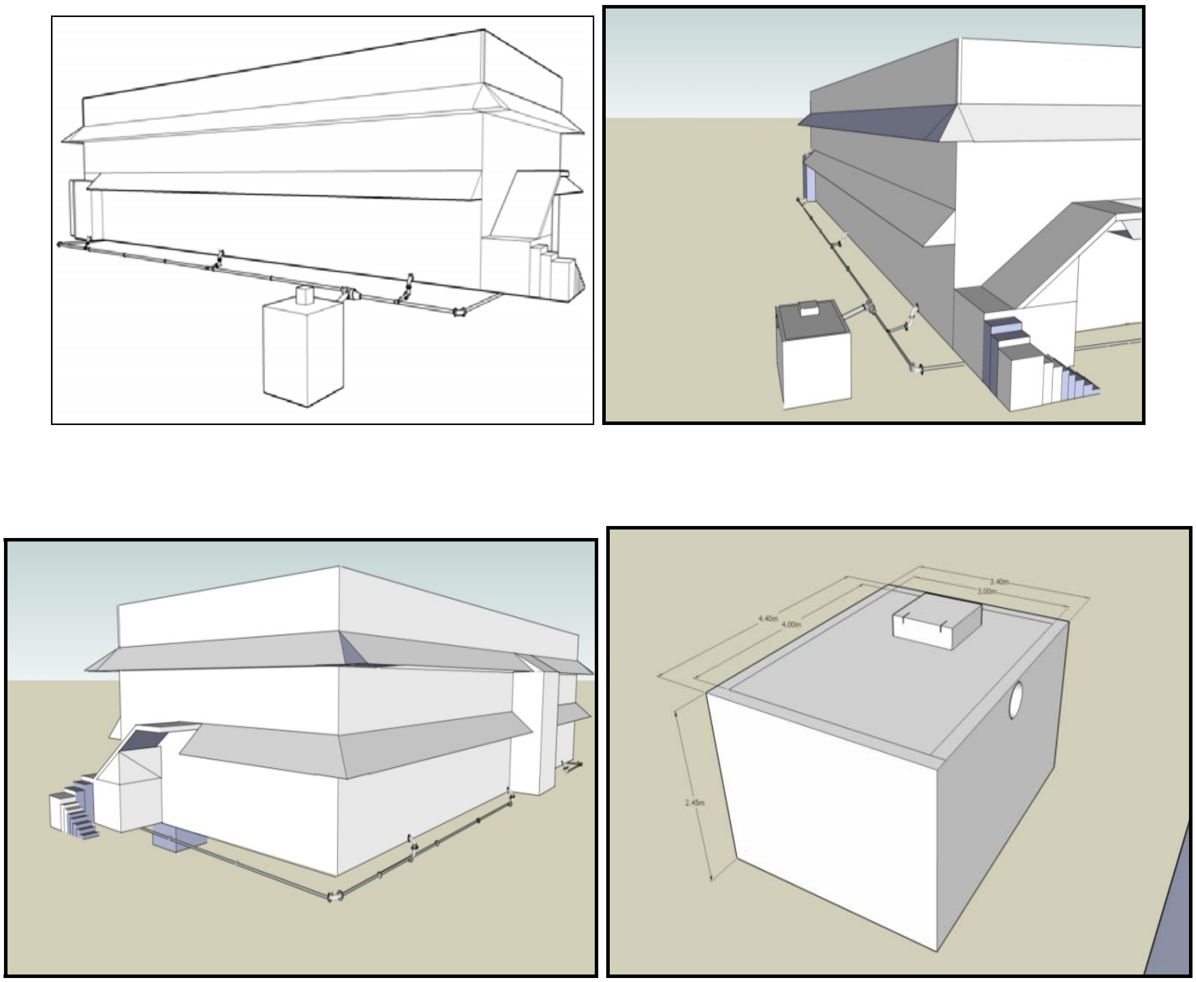

Figure 11. Design Sketch of Rainwater Harvesting System

4.3 *Community Care*

As previously identified, the long term community care of this area must be addressed for future sustainability. Because this region in the Dominican Republic is a major revenue generating region for the entire country, federal investment should be committed to this area. The small amount of infrastructure already present in the area has been formed in a small part by the federal government and in a large amount by resort investments. Some resorts spent money on the infrastructure including the airport and major roadway connecting the airport to Punta Cana. It has been speculated however that the addition of the major roadway to connect the airport and the resort area was invested by several resorts in order to avoid having tourists travel through Veron to get to Punta Cana. The social issue behind the rationale of investing in infrastructure is another topic entirely that is not addressed in this report.

Committing federal funding to improve the infrastructure of Veron would instill more pride in the community. If residents had regular trash collection and water services, they would be more likely to use these services. Without these services however, it is nearly impossible to instill sustainable values within the community. Additionally, if investments were made in the construction infrastructure including schools and homes, people could be instilled with the value of a long-term home. Currently, many residents live in tin huts that are easily constructed with available materials. If homes became more permanent with concrete and brick, appreciation of the home would increase. In the future, all of these scenarios could be studied in order to determine the exact change of community care based on a particular action.

In Punta Cana, community care can stem from the resorts shifting towards eco-tourism. Eco-tourism is a booming industry that invites tourists who care about environmental preservation into the area. The PuntaCana Resort is slowly moving towards increasing sustainability as a marketing point for the resort. Other resorts would potentially follow suit if shown a financial benefit in eco-tourism.

5. Conclusion

Identifying the different community needs throughout the region is the first step towards building a sustainable water future. This research begins to tackle the issues associated with tourism and development in the province of La Altagracia. As shown through the site review, different areas within a region can have widely varying problems even if the areas are only mere miles apart. Technological solutions for the area include employing reverse osmosis water treatment technology but also need to investigate other appropriate technologies such as rainwater harvesting and reuse. In the future, a more expansive look at the salt water intrusion levels needs to be completed. This evaluation should include an accurate mapping of the fresh groundwater table. It should also analyze the rate at which the water is being consumed. Analyzing the water consumption will be difficult unless the resorts are willing to participate. Finally future study should determine the rate at which the saltwater is impeding onto the fresh water table. This information could be a strong source of persuasion for the resorts to work towards sustainability. A study of salinity is the most critical step towards the future.

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Appendix

Table A: Water Quality Sampling August 2008 in Veron

	GIS	Conductivity (µS)	TDS (mg/L)	ORP (mv)	pH	Temp (F)	Con 2	Temp 2 (°C)
1	A9	1100	786.6	217	7.81	81.5	1280	27.7
2	A17	964	682.5	171	7.68	84.5	1057	29.4
3	A42	1195	853.4	168	7.89	86	1290	30
4	A32	1106	788.5	165	7.84	83.9	1208	28.8
5	A57	1177	796	169	7.77	84.5	1193	29.3
6	A59	1120	797.8	170	7.77	83	1190	28.5
7	C26	1045	742.6	174	7.48	84.1	1140	29.8
8	C21	777.3	544.8	176	7.47	83.2	859.4	28.3
9	C97	862.6	607.1	156	7.74	85.4	936	30.2
10	C101	680	472.2	169	7.66	83.5	754	28.3
11	Bavarito's	742	516.6	167	7.68	84.6	807	29.8
12	D1L42	672.1	467.6	171	7.85	82.9	746	28.7
13	D1L12	573	398.3	197	7.62	82.3	645	28
14	DX4	674.6	469.2	169	7.67	83.6	759	28.5
15	H13	699.4	486.7	155	7.68	84.5	772	29.2
16	H23	700.2	488.3	167	7.58	82.3	785	27.7
17	D2L19	658.8	452.8	176	8.22	83.4	743	28.4
18	Travis'	485.7	331.6	175	7.77	7.77	566	30.4
19		433.4	295.9	179	7.76	7.76	493	28.4
20		404.7	275.2	174	8.02	8.02	462	29.7
21		369.6	249.7	170	8.12	8.12	418	29.7
22		422.5	287.1	168	7.9	7.9	486	30.7
23		434.5	296.3	181	8.11	8.11	493	29.8

Table B Water Sampling Results Veron August 2009

	Conductivity (µS)	TDS (mg/L)	ORP (mv)	pH	Temp (°C)
Clinic	542.5	360.2	177	7.72	27.4
School	574.4	381.3	179	7.58	29.3
1	742.7	498.9	165	7.55	29.1
2	786.2	528.4	170	7.61	28.9
3	721.1	482.2	171	7.75	29.2
4	742.3	496	161	7.78	30.8
5	740.2	495.7	165	7.6	30.4
6	719.2	481	174	7.5	29.5
7	677	452	176	7.7	29.7
8	603.5	400.8	174	7.7	30.4