Virgin Islands Water Resources Research Institute
Annual Technical Report
FY 2010

Introduction

The U. S. Virgin Islands are located between the Atlantic Ocean and the Caribbean Sea in an area about 1,200 miles southeast of Miami, Florida and 80 miles southeast of San Juan, Puerto Rico. The islands are a territory of the United States. The USVI consists of four principal islands, St. Thomas, St. Croix, Water Island and St. John with a combined area of approximately 137 square miles extending about 60 miles west to east. In general, the islands are of volcanic origin and are consequently relatively mountainous. Historically, rain water harvesting has been a principal source of potable water for the residents of the USVI with some reliance on ground water. Surface water supplies are virtually non-existent. In recent times, desalinated water satisfies most of the needs of the population of about 115,000 persons and is the source of water for the islands' limited public water distribution systems. Wastewater disposal continues to be a concern, though recently, major improvements have been made in the wastewater collection and treatment systems.

The Virgin Islands Water Resources Research Institute (VI WRRI) is hosted by the territory's only institution of higher education, the University of the Virgin Islands (UVI). UVI, founded in 1962, is a land-grant, Historically Black College or University (HBCU) with a student population of about 2,700. It has campuses on both St. Thomas and St. Croix and a research station on St. John. UVI is primarily an undergraduate institution but there are also graduate programs in Business, Teacher Education, Public Administration and Marine Science. As is the case throughout the U. S. Virgin Islands community, the university population consists of a diversified mix of persons coming from not only the Virgin Islands and the Caribbean area but from the U. S. mainland and other areas throughout the world as well. UVI maintains many active collaborative relationships with a wide range of universities in order to maximize its ability to serve the needs of the Vigin Islands community.

The VI WRRI is one of the smaller institutes in the U. S. Geological Survey's State Water Institute Program. It has no full-time staff and in order to make maximum use of resources available to it, maintains no distinct facilities at UVI but works collaboratively with other UVI units and entities outside of the university. It has always kept a focus on addressing water resources research issues particularly relevant to tropical island communities and is known for work done in areas such as rain water harvesting, alternative on-site sewage disposal systems and investigation of applicable indicators in tropical water supply systems. The research, information dissemination and training activities conducted by the VI WRRI are guided by an advisory group.

Research Program Introduction

Research projects reported on in this annual report include those that were not completed during the previous reporting period and those that were funded for execution in FY 2010, the final year of this five-year award cycle. Research projects for FY 2010 focused on matters having to do with enhancement of cistern water quality, sediment generation and control, water use in rice production and climate variability in the Lesser Antilles. Results of the research conducted have been summarized in project completion reports and in some instances presented at conferences and workshops and published in scholarly journals. Many of the research projects also provided training opportunities for undergraduate and graduate students.

Water Quality in Virgin Islands Rain Water Collection Cisterns.

Basic Information

Title:	Water Quality in Virgin Islands Rain Water Collection Cisterns.
Project Number:	2008VI109B
Start Date:	3/1/2009
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Water Quality
Focus Category:	Water Quality, Toxic Substances, Sediments
Descriptors:	None
Principal Investigators:	Thomas Archibald, Stanley L. Latesky

Publication

1. Latesky, Stanley, Thomas Archibald, 2011, Water Quality in Virgin Islands Rain Water Collection Cisterns, Virgin Islands Water Resources Research Institute, University of the Virgin Islands, St. Thomas, U. S. Virgin Islands.

PROBLEM AND RESEARCH OBJECTIVES

Water quality in cisterns is a major concern in the Territory of the US Virgin Islands. As part of our endeavour to do a detailed survey of the water quality in the Territory, a number of water samples were collected for inorganic and organic analysis. To date, we have done a detailed analysis of the anionic inorganic species present in the forty water samples using a Metrohm 850 Professional Ion Chromatographic system and a comprehensive metal-ion analysis using a Varian Inductively Coupled Plasma-Mass Spectrometer (ICP-MS). Samples were collected from various sites on St. Thomas and St. John.

METHODOLOGY

Stock solutions of standards for anions and cations were obtained from Metrohm and Inorganic Ventures respectively. The 10,000 ppb inorganic stock solution from Inorganic Ventures contained each of the cations measured in the study. Separate 1000 ppm stock solutions of each anion were used to prepare stock solutions of each concentration for anion analysis. Compressed gases (Ar, He, H_2) were supplied by Island Gas as ultra-high purity grade. Tracemetal grade acids and bases (Fisher Scientific) were used for all acid or base matrix preparations. Reagent grade (18.2 M□) water was prepared using a Barnstead Diamond deionization equipped with a UV lamp to remove Total Organic Carbon from the water. Feedwater for the deionizer was supplied by a Barnstead RO water system with raw water supplied by the UVI water system. Data analyses were conducted using a five point calibration curve based on the standards shown below (1, 5, 10, 15, and 20 ppm) for (in order of elution) fluoride, acetate, chloride, nitrite, bromide, nitrate, phosphate, and sulfate.

Cation analysis

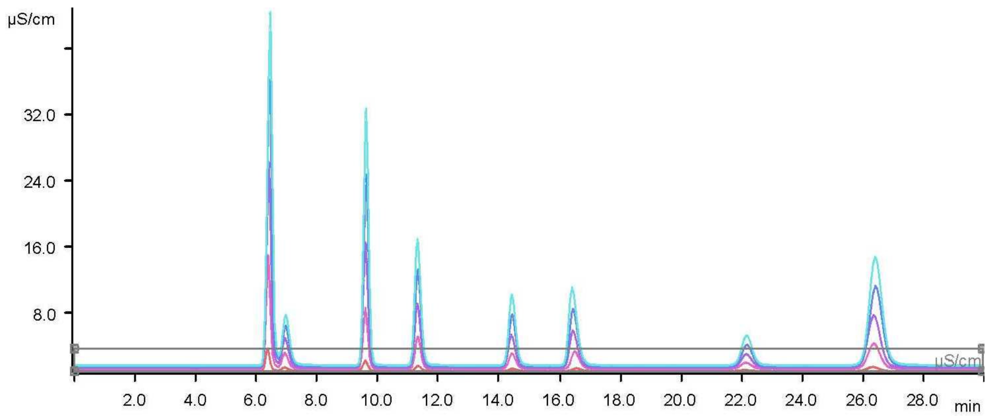
Cation analyses were conducted using a Varian 820-MS ICP-MS equipped with a Varian SPS-3 autosampler and a collision reaction interface. Water samples were collected and stored in clean acid-washed plastic bottles. All glassware and plasticware were washed with 2% nitric acid in water and then rinsed with 18.2 M□ ultrapure water. Triplicate runs were collected for each sample, with 20 data acquisitions per run collected. The triplicate data were averaged and data was fit to a standard curve for each element analyzed. A set of standards were prepared by serial dilution of the commercially obtained stock solution. Interferences in some cations (e.g. As) were minimized by using the Collision Reaction Interface (CRI), using ultra-high purity hydrogen gas.

In order to remove any organic materials, water samples for inorganic analysis were digested overnight using a Varian Hotblock at 373 K. A 20 mL aliquot of each water sample was digested by adding a mixture of 6M HCl and 18 HNO_3 (aqua regia) and were then heated overnight to dryness. The samples were re-constituted by adding 20 mL of 2% nitric acid.

Anion analysis

Anion analyses were conducted using a Metrohm 850 Professional IC system operating at an optimum pressure of 10.8 megapascal (MPa) at a flow rate of 0.7 mL per minute at a temperature of 30 ^{o}C. The IC column used for the analyses was a Metrosep A Supp5-250 250 mm column which gave optimum separation of the typical inorganic anions found in drinking water. The

instrument used a conductivity detector equipped with a cation suppressor. The eluent used in the analyses was a mixture of 1.0 millimolar (mM) sodium bicarbonate and 3.0 mM sodium carbonate. The eluent was prepared from concentrate using a Metrohm 845 eluent synthesizer.
Water samples for anionic analysis were used as collected with no pre-treatment. The water samples were pre-filtered using a pre-filter attached to the instrument. The IC column was protected by a guard column attached at the entrance to the column.



	Date	Number	Ident	Sample type	Method	Analysis	Legend	Display
1	2009-01-15 13:06:09 UTC-4	1	Standard 1	Standard 1	anion2	Anion 2		on
2	2009-01-15 13:38:51 UTC-4	2	Standard 2	Standard 2	anion2	Anion 2		on
3	2009-01-15 14:11:34 UTC-4	3	Standard 3	Standard 3	anion2	Anion 2		on
4	2009-01-15 14:44:16 UTC-4	4	Standard 4	Standard 4	anion2	Anion 2		on
5	2009-01-15 15:16:58 UTC-4	5	Standard 5	Standard 5	anion2	Anion 2		on

Figure 1: Standard calibration chromatograph

PRINCIPAL FINDINGS AND SIGNIFICANCE

Anion analysis
A total of forty water samples were analyzed. The samples analyzed represented a cross-section of cisterns on St. Thomas, St. John, and Water Island. As expected, the major anion component was chloride with smaller amounts of nitrate, sulfate and acetate detected. The concentration of chloride ranged from 8 ppm to 60 ppm, depending on the island and location of the cisterns. As a comparison, tapwater (WAPA Desalinated) was also analyzed. The results are highlighted in the Figures 1-4 given below. The smaller peaks are fluoride at around 7 minutes (from cisterns replenished by WAPA water) and nitrate at around 18 minutes. WAPA water showed a detectable concentration of sulfate (at around 27 minutes) because their source of water is seawater.

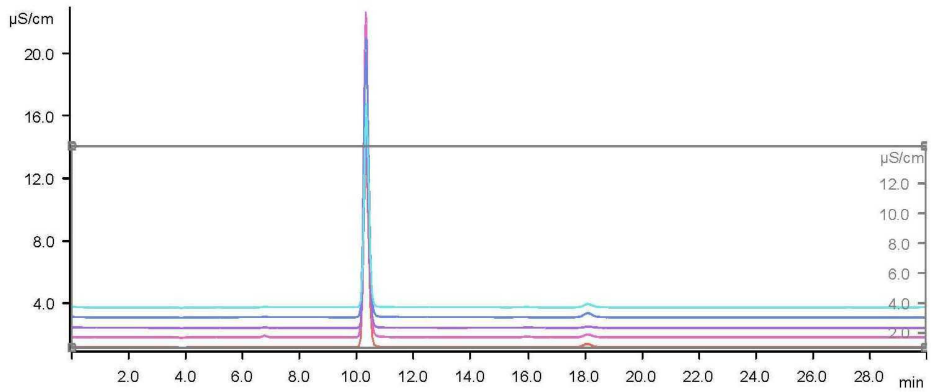


Figure 2: IC for the Water Island samples

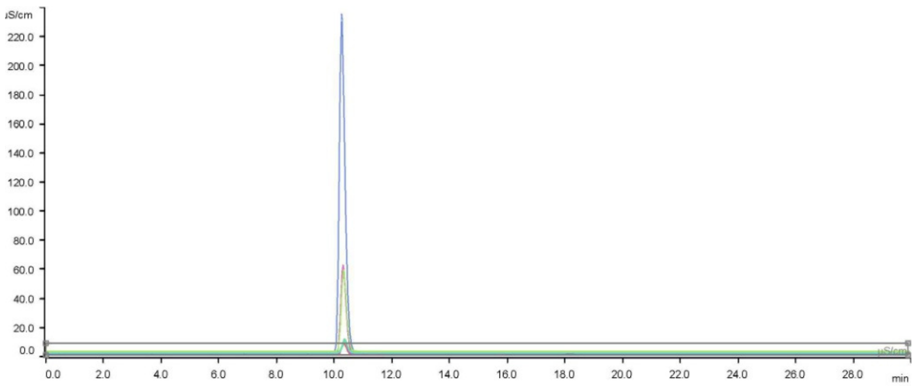


Figure 2: IC for the St. John water samples

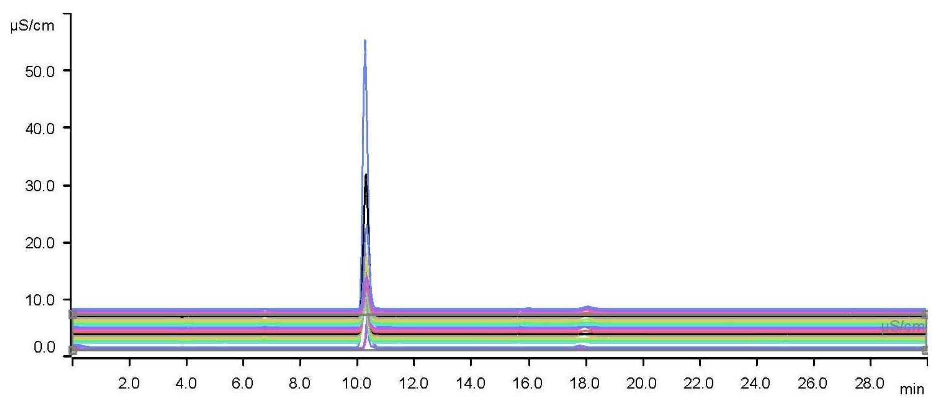


Figure 3: IC for the St. Thomas water samples

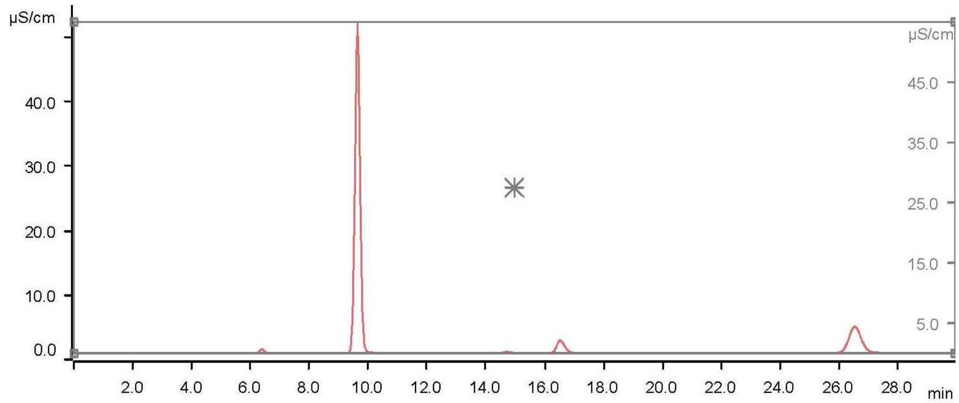


Figure 4: IC for UVI tap water

Cation Analysis

The water samples analyzed for metal content came from a range of cisterns on St. Thomas and St. John. In all cases, standard curves met the criteria of a correlation of greater than 0.999 (The full analytical report is available, including standard curves, from the authors, pdf format, 86 pages).

The data demonstrated that in the majority of the samples, very small amounts (sub-ppb) level of metal ion. Those samples followed by a b are where the metal ion is below the detection limit set by the analytical standard range. Those with an x are where the metal ion concentration is above the analytical standard range. The few metal ions that were found in significant amount, albeit still no more than 2000 ppb (2 ppm), were a few samples that demonstrated high concentrations of Al, Zn, and Cu. This could be explained by the fact that some of the roofs might be galvanized or use Al sheeting. The increased Cu in some of the cistern water might be explained by Cu plumbing within the cistern.

Conclusions and future work

The small data set indicates little or no unexpected concentrations of anion or cation contaminants in any of the cistern samples analyzed. The range in chloride concentration is more than likely due to some cisterns being occasionally replenished by trucked in WAPA water, and the occasional sample containing high Al, Zn, and Cu can be explained by the presence of galvanized or aluminum roofing or copper plumbing. Future work will involve analysis of water for organic contaminants using solid-phase extraction to concentrate the contaminants followed by analysis using either gas-chromatography mass-spectrometry (GC-MS) or liquid-chromatography mass-spectrometry (LC-MS) and extending the study to include St. Croix. We also plan on beginning a monitoring plan to examine how African dust and volcanic ash affect the concentration of trace-metals in cistern water quality in the Territory.

Investigation of Sediment Export from St Thomas Watersheds

Basic Information

Title:	Investigation of Sediment Export from St Thomas Watersheds
Project Number:	2009VI152B
Start Date:	3/1/2009
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	VI
Research Category:	Water Quality
Focus Category:	Sediments, Non Point Pollution, Water Quality
Descriptors:	None
Principal Investigators:	Kerry A. Brown, Gaboury Benoit

Publication

1. Benoit, Gaboury, Donna Nemeth, 2011, Investigation of Sediment Export from St. Thomas Watersheds, Virgin Islands Water Resources Research Institute, University of the Virgin Islands, St. Thomas, U. S. Virgin Islands, 34 pages.

PROBLEM AND RESEARCH OBJECTIVES

Coral reefs and other vulnerable nearshore marine resources of the United States Virgin Islands are suffering from the impacts of multiple stressors. Among the most important of these is fine-grained sediment eroded from land and delivered by guts to the coastal zone. Steep slopes, erodable soils, widespread soil disturbance (for land development and road building), and inadequate use of erosion prevention and control measures lead to accelerated erosion and sediment export. Short distances and steep slopes mean that USVI watersheds are closely coupled with adjacent marine ecosystems.

Corals must clear themselves of deposited sediments to obtain prey and, more importantly, to allow symbiotic zooxanthellae to photosynthesize. Even non-deposited sediments can shade corals, reducing photosynthetic efficiency. Dealing with fine sediments requires expenditure of unnecessary energy, which when combined with predation, elevated temperatures, disease, predation, and physical disturbance can cause coral morbidity and mortality. A better understanding of erosion, transport, and delivery of fine-grained sediments would inform better management to protect fragile coral reef ecosystems from the impacts of onshore land development.

METHODOLOGY

There are several approaches to understanding erosion and sediment fluxes:

- examining the sources of eroded material,
- measuring the transport of sediment,
- and assessing the impact and final repository of eroded material.

The first and last methods (source and sink evaluation) have the advantage of yielding net effects and of integrating the impact of processes over long time periods. They have the disadvantage of being insensitive to short term processes, so they reveal less information about mechanisms. We combined short-term, real-time measurements with longer-term integrative analyses to harness the advantages of both approaches.

Stream Monitoring

A goal of this study was to continuously monitor discharge and suspended matter in Dorothea gut for a period of at least a year. This was facilitated by installing a V notch weir as an addition to an existing broad crested weir built by the USGS.

A YSI 6920 Multi Parameter Water Quality sonde was deployed in Dorothea Gut by attaching it in the pool behind the weir. The sonde was equipped with probes to measure pressure (stage/water depth), turbidity (a surrogate for suspended sediment), temperature, dissolved solids, dissolved oxygen (DO), and pH.

Rain gauging

In conjunction with the stream monitoring, we deployed two Rainwise RAINLOGGER digital rain gauge/data logger systems.

Coastal Pond Sediment Accumulation Rate Analysis

Sediment cores were collected from ponds along the coast of St Thomas. Geologically, these systems tend to be small embayments whose connection to the sea has been closed by some combination of reef building and longshore drift creating berms rising 1 to 2 m above sea level.

PRINCIPAL FINDINGS AND SIGNIFICANCE

General Findings

Compared to much of St. Thomas, especially the eastern end, the watersheds of the four ponds tested have relatively low levels of land development. This sampling bias is because there are no ponds on the island that have watersheds that are both large and heavily developed. We judged larger watersheds to be more likely yield results that were more representative. In the future we will study some ponds with smaller watersheds with higher levels of land development, though there are not many candidates.

Evaluating the four ponds measured so far, Sediment Accumulation Rates (SARs) are low. A simple calculation can be used to place the SARs in the context of erosion rates in their watersheds. Sediments in these ponds typically have a bulk density of 0.3 g/cm^3. (We use this term in the sense of dry mass per volume.) A SAR of 0.1 cm/yr then translates to deposition of about 3000 kg ha^{-1} yr^{-1} in the ponds. For a pond with a watershed 40 times its size that would mean an erosion rate of 75 kg ha^{-1} yr^{-1}, which is considered to be a very low value. Looking at the four ponds, we calculate delivery rates of 103, 75, 220 and 1250 kg ha^{-1} yr^{-1}, assuming 100% capture. These values compare favorably with those measured on St John for hillslope plots (10 – 270 kg ha^{-1} yr^{-1}) and zero and first order catchments (10 and 80 kg ha^{-1} yr^{-1}).

Considering the steepness of the slopes and level of development, we expected SARs to be higher. This only occurred in Sapphire Pond, which is both small in comparison to its watershed, and whose local land use (pasture or former pasture) could be expected to generate a large amount of eroded sediment. The low SAR values we measured imply either that (1) the ponds are very inefficient sediment traps, (2) erosion is minimal, or (3) transport of eroded material is negligible. We believe that mechanisms 2 or 3 are the most likely explanations for the low SARs. (1) Based on the size of the ponds compared to their watersheds, the depth of added water that would need to be added before they would overflow, typical rainfall amounts, and the amount of runoff that would be generated per storm, the ponds should be able to contain most of the inflow they receive, except in very large storms. Water residence times thus being high, and settling depths short, the ponds should be efficient sediment traps. (2) Much of the watershed area of these ponds is undisturbed. On St John, it was found that disturbed lands (especially unpaved roads) were the main source of eroded material. In the watershed of these ponds, most land can be expected to produce little eroded material, despite their steep slopes. (3) Much of the steep uplands above these ponds are upslope from undisturbed, vegetated lands. They should not generate significant overland flow that could carry eroded material. Thus, even if significant erosion does occur, much of the material is likely to be redeposited before it can reach the ponds.

Conclusion

The management implication of these results is important. Erosion from undisturbed watersheds on St Thomas is naturally low. The nature of soils, vegetation, and climate is such that little material is eroded or that which is quickly redeposited despite steep slopes. This means that small areas of disturbed soils, mainly associated with land development, can contribute a vastly disproportionate share of sediment to downslope ecosystems. On the positive side, because these developed areas tend to be small (typically the size of building lots), erosion control measures can be employed cost effectively. Also, because there is an obvious link between the erosion source and an individual developer or builder, responsibility is clear and enforcement should be straightforward.

Additionally …

- Eight student term papers for the course Caribbean Coastal Development were based on data collected for this project.
- Two peer-reviewed papers are in preparation based on this project. Working titles are:
    - Continuous monitoring to assess stream export of sediment from Dorothea Gut watershed in St Thomas, USVI
    - Watershed erosion as revealed by sediment capture in coastal ponds of St Thomas, USVI
- Results of the research were presented in two Yale courses: F&ES 729 Caribbean Coastal Development, and F&ES 708 Biogeochemistry and Pollution
- The research was highlighted in a talk in the Yale School of Forestry and Environmental Studies faculty seminar series.

Point-of-Entry (POE) Cistern Water Purification Units (CPU) Development

Basic Information

Title:	Point-of-Entry (POE) Cistern Water Purification Units (CPU) Development
Project Number:	2010VI169B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	
Research Category:	Engineering
Focus Category:	Water Quality, Water Supply, Treatment
Descriptors:	None
Principal Investigators:	Sangchul Hwang, Henry H. Smith

Publications

1. Rodriguez, Laura. May 2012 (expected), Disinfection by-products occurrence and Escherichia coli removal in a point-of-entry cistern purification unit. Master of Science Thesis, Department of Civil Engineering, College of Engineering, University of Puerto Rico, Mayaguez, PR.
2. Rodriguez, L., Hwang, S. Disinfection By-products Occurrence and Escherichia-coli Removal in a Point-of-Entry Cistern Purification Unit (POE-CPU) , XVI Sigma Xi, University of Puerto Rico, PR, April 12, 2011.
3. Rodriguez, L., Hwang, S., Sevillano, M., Concepcion, D. Point-of-Entry (POE) Cistern Water Purification Unit (CPU) Development , XV Sigma Xi, University of Puerto Rico, PR, April 8, 2010.
4. Hwang, Sangchul, Henry Smith, 2011, Point-of-Entry (POE) Cistern Water Purification Units (CPU) Development, Virgin Islands Water Resources Research Institute, University of the Virgin Islands, St. Thomas, U. S. Virgin Islands, 23 pages.

PROBLEM AND RESEARCH OBJECTIVES

Desalination supplies about 80% of the water used in the United States Virgin Islands (USVI). Despite this fact, more than 50% of the residences in the USVI use rainwater cistern (Brin et al., 2003). Annual rainfall averages 40 inches in USVI and is very seasonal so that desalinated water is often transported to refill the cisterns. From that point, there is a potential for improved water supplies to get exposed to secondary contamination from pumps, pipes and the trucks, resulting in causing infectious diseases and other enteric illness (Sobsey et al., 2008).

In addition, there might be contamination of rainwater before collected to the cisterns due to urban pollution, bird and reptile waste materials and particulate matter deposited (Chang et al., 2004; Evans et al., 2006; Simmons et al., 2001). Also, if the cisterns are old and dirty due to poor maintenance, there is a potential of contamination of the stored cistern water. Another case of cistern water contamination can be due to aged cistern structure, thereby infiltration of contaminants from the surrounding contaminated soil and groundwater to the cisterns (Isquith and Winters, 1987).

The goal of the first-year project was to develop and evaluate a point-of-entry (POE) cistern rainwater purification unit (CPU) with respect to physiochemical and bacteriological water quality. POE CPU could be used by residents voluntarily with the expectation that the units can provide a protective measure if contaminations are present due to dirty rainwater or mismanaged cisterns. The POE CPU can also be used in a reactive mode, where the residents could take action in response to suspected or confirmed cistern water contaminations.

Stretching the first-year project's goal, the current second-year project was conducted on the disinfection byproducts (DBPs) production potential in the final disinfected effluent from the POE CPU. Pathogens, such as *Giardia*, are often found in source water, and can cause gastrointestinal illness and other health risks (e.g., diarrhea, cramps, vomiting). To kill (or inactivate) these pathogenic microorganisms, water needs to be disinfected. However, disinfectants like chlorine can react with naturally-occurring materials (NOM) in the water to form DBPs. These byproducts include trihalomethanes (THMs), haloacetic acids, chlorite and bromate. DBPs may lead to increased health risks as potential carcinogens and the cause of reproductive and development defects in laboratory animals and human, if consumed in excess of EPA's standard over many years (Hamidin et al., 2008; Wang et al., 2007). Due to potential carcinogenic and toxic characteristics of these byproducts, EPA has developed the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBP rule) to protect public health by limiting exposure to them (EPA, 2006). This Stage 2 DBP rule is effective on July 29, 2009.

METHODOLOGY

Filtration and Disinfection Materials

Three different sizes of sand were purchased from the Standard Sand & Silica, Co.. The sands were manufactured specifically for the compliance with AWWA Standard B100 and are listed with NSF Standard 61 as an approved filtration sand supplier and for the use of filtration systems. Commercial gravels in sizes of 0.25~0.75" was purchased for construction of the gravel filter. The lab-scale filtration unit was constructed with glass columns (7" in diameter and 12" long). For disinfection, 0.1% sodium hypochlorite (NaOCl) solution was applied to filtered effluent.

Rainwater

Rainwater was collected periodically and stored in a refrigerator at 4^{o}C prior to use. It was analyzed for the key water quality parameters. Table 1 contains the rainwater characteristics reported by other studies in comparison to the current study.

Table 1. Comparison of rainwater characteristics.

	Villarreal and Dixon (2005)	Appan (1999)	Hwang (2010)	Current study
pH	5.2-7.9	4.1+/-0.4	5.8-6.2	4.7-6.9
BOD (mg/L)	7-24			
COD (mg/L)	44-120		77	0-75
TOC (mg/L)	6-13			
Turbidity (NTU)	10-56	4.6+/-5.7	0.7-1.3	0.9-6.9
Nitrate (mg/L NO3)			5-7	0.5-2.3
Phosporus (mg/L PO4)			0.025	
TS (mg/L)	60-379			
SS (mg/L)	3-281	9.1+/-8.9		
Conductivity (uS/cm)			26-28	9.6-40.5
Total coliform (#/100 mL)		92.0+/-97.1		
Fecal coliform (#/100 mL)		6.7+/-8.9	2-10	

Lab-scale POE CPU

A lab-scale filtration and disinfection unit was constructed (Photo 1). For the sand filtration column, three different sizes of sand were used (effective size of 0.18, 0.55, and 1.10 mm). Distribution and selection of sands were decided in accordance to another small drinking water system project that the PI is working on at a field (Hwang et al., 2009).

Photo 1. POE CPU set up.

For the filtration, rainwater was pumped at 0.09 gal/min which is corresponding to 0.50 gal/min/ft^2 as shown below:

$$SFR = \frac{0.09\,\frac{gallon}{min}}{0.182\ ft^2} = 0.50\,\frac{gal}{\min ft^2}$$

For disinfection, a commercial liquid NaOCl solution (5.25%) was diluted to 0.1%. The solution was pumped to the effluent from the sand filtration unit at a flowrate of 0.03154 mL/min. The target disinfectant concentration was set at 0.5~1.0 mg/L in the effluent.

Backwash of the sand filtration unit was conducted at a flow rate of 0.275 gal/min. The stored disinfected filtration effluent was used for the backwash. The flowrate was corresponding to 1.51 gal/min/ft^2 as shown below:

$$BWR = \frac{0.275\ gal/min}{0.182\ ft^2} = 1.51\,\frac{gal}{\min ft^2}$$

E coli

Escherichia coliforms were purchased from the ATCC and used for the indicator microorganisms for disinfection efficiency. They were maintained for use via enrichment technique.

POE CPU Run: Physiochemical Water Quality Parameters

The POE CPU was run for assessment of physiochemical water quality parameters. Due to shortage of rainwater, river water on campus was collected and diluted with deionized water at a ratio of 1:1 (v/v), to which E coli at a stationary growth was added at 0.1% (v/v). Samples were taken after a 30- and 60-min run from the influent cistern, the gravel filter effluent, the sand filter effluent, and the final disinfected effluent. One percent chlorine stock solution was prepared from 5.25% NaOCl solution. It was added to the sand filter effluent at an initial concentration of 5 mg/L. For the analysis of residual chlorine, a 30-min contact time was provided.

POE CPU Run: DBP Production Potential

The POE CPU was run for assessment of DBP production potential. This time, river water was used as collected. E coli at a stationary growth was spiked at 0.1% (v/v). The run was extended to 90 minutes. One percent chlorine stock solution was added at an initial concentration of 10 mg/L. Same as before, a 30-min contact time was provided for residual chlorine analysis.

PRINCIPAL FINDINGS AND SIGNIFICANCE

POE CPU Challenge: Physiochemical Water Quality Parameters

The POE CPU was challenged with respect to its efficiency for the reduction of turbidity and COD. As shown in Figure 8, the values of the influent and effluents were in the neutral range (6.9~7.1). The sand filter achieved a 50% turbidity reduction even after a 60-min run. The final disinfected effluent had less than 1 NTU (Figure 1).

COD showed a different trend. After a 30-min run, both the gravel and sand filter produced about 25~30% higher COD concentrations than that in the influent. This might be attributed to poor backwashing of the gravel and sand filter prior to the experiment. However, after disinfection, an overall 40% COD reduction was achieved with the POE CPU. In comparison, the POE CPU showed a better performance after a 60-min run in terms of COD reduction. Both the gravel and sand filters achieved gradual reduction in COD. An increase in COD after disinfection after a 60-min run was attributed to lower chlorine dose (by 60%) for disinfection.

POE CPU Challenge: DBP Production Potential

The POE CPU run was extended to 90 mins in an additional experiment for assessment of DBP production potential. Figure 1 shows a relationship between the chlorine demand and THM concentration after 30-min disinfection contact time. The chlorine demand is defined as the difference between the initial chlorine concentration and the final one after 30 minutes. There was an inverse relationship: the greater chlorine demand, the lower THM concentration was found, in general.

DBP production potential is influenced by the amount and chemical characteristics of NOM. It is also in a function of temperature, pH, reaction time, and chlorine concentrations (Reckhow et al., 1990). As the current experiment had only three data points under limited operating parameters, it is hard to clarify the underlying mechanism for such inverse relationship between the chlorine demand and THM concentration. Therefore, more study on the aspect is warranted.

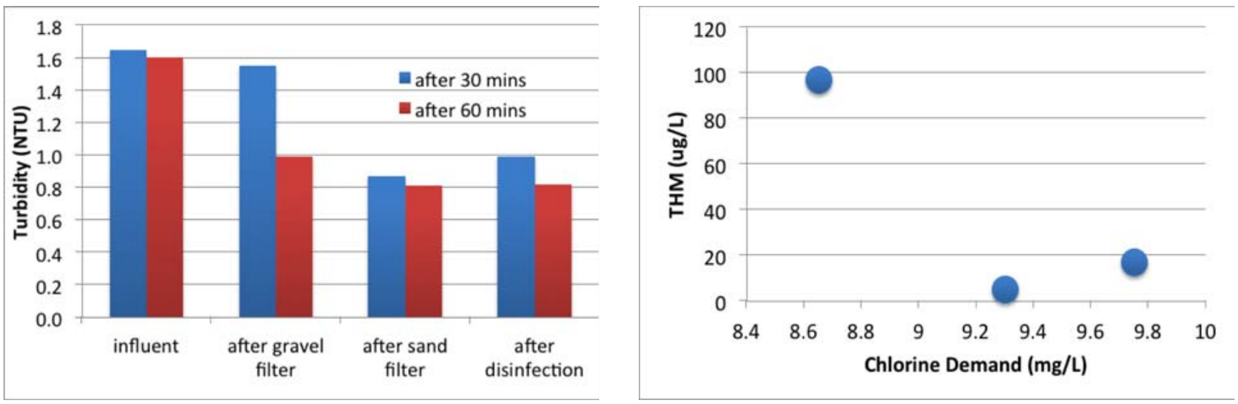


Figure 1. Turbidity (left) and DBP production (right) results from POE CPU challenge.

CONCLUSIONS

A lab-scale POE CPU was developed and tested with respect to physiochemical and microbial water quality parameters and DBP production potential. Although more robust study is recommended in the future, the following were obtained:

- The POE CPU was capable of reducing the turbidity lower than 1 NTU, while complying with the EPA standard with respect to microbial reduction.;
- Total THM concentrations after 30-min chlorination contact time were found to be lower than the US EPA standard 80 ppb.;
- However, the rainwater characteristics were found very different spatially and temporally. Therefore, more robust investigation is warranted to conduct to assess the POE CPU with dissimilar rainwaters with respect to microbial controls and DBP production potential.; and
- Heavy metal analysis is also recommended for the future study as rainwater might contain hazardous heavy metals due to, for examples, atmospheric deposition and leaching from the roofing materials (Baez et al., 2007).

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MEASUREMENT OF PARTICULATE ORGANIC MATERIAL AND EROSION RATES IN SMALL SUBTROPICAL WATERSHEDS ON THE EAST END OF ST. CROIX, USVI

Basic Information

Title:	MEASUREMENT OF PARTICULATE ORGANIC MATERIAL AND EROSION RATES IN SMALL SUBTROPICAL WATERSHEDS ON THE EAST END OF ST. CROIX, USVI
Project Number:	2010VI170B
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Congressional District:	Territory of the US Virgin Islands
Research Category:	Water Quality
Focus Category:	Sediments, Water Quality, Management and Planning
Descriptors:	None
Principal Investigators:	Bernard Fernando Castillo, Carlos E Ramos-Scharron, Kynoch Reale-Munroe

Publications

1. Reale-Munroe, Kynoch; Carlos Ramos-Scharron, Bernard Castillo II, 2011, Measurement of Particulate Organic Material and Erosion Rates in Small Subtropical Watersheds on the East End of St. Croix, U. S. Virgin Islands, The Water Resources Research Institute, University of the Virgin Islands, St. Thomas, U. S. Virgin Islands, 32 pages.
2. Cumberbatch, Jewel; Forbes, Anthonio; Bernard Castillo II, and Kynoch Reale-Munroe, 2011, Preliminary Results: Measurement of Sediment Production and Particulate Organic Material in Small Subtropical Watersheds on the East End of St. Croix, USVI in Proceedings from UVI-ECS 9th Annual Spring Research Symposium, College of Science and Mathematics, St Croix Campus, University of the Virgin Islands, St. Croix, U. S. Virgin Islands.

PROBLEM AND RESEARCH OBJECTIVES

A primary concern in the U. S. Virgin Islands (USVI), is that increased soil erosion associated with human induced land use changes is massively contributing sediment laden runoff into the bays, which is adversely affecting the coastal marine environment (Hubbard, 1987; Ramos-Scharrón and MacDonald, 2007). In the USVI, unpaved roads, eroding foot trails, altered drainage patterns combined with generally thin surficial soil layers, steep topography, infrequent, but often intense rainfall, and current land development practices create conditions that are especially susceptible to erosion and sediment delivery.

Terrestrial erosion not only degrades the physical and chemical characteristics of receiving water bodies, but also depletes surficial soils of organic material, which effectively decreases soil quality. Particulate organic material is thought to be a primary source of nutrients to support abundant plant growth. Increased vegetative cover stabilizes soil and reduces excessive erosion.

The specific objectives of this study were (1) to quantify and compare surface erosion rates from various disturbed and undisturbed surfaces in two watersheds located on the East End of St. Croix, USVI and (2) to quantify the particulate organic material present in the sediment samples generated in each watershed.

METHODOLOGY

Field Component:

Monthly and long-term (30-year) mean precipitation data was acquired from the National Climatic Data Center for the East Hill and Cotton Valley stations during the study period. Precipitation on East End and Boiler Bay is expected to be similar to that at East hill and Cotton Valley (Figure 1).

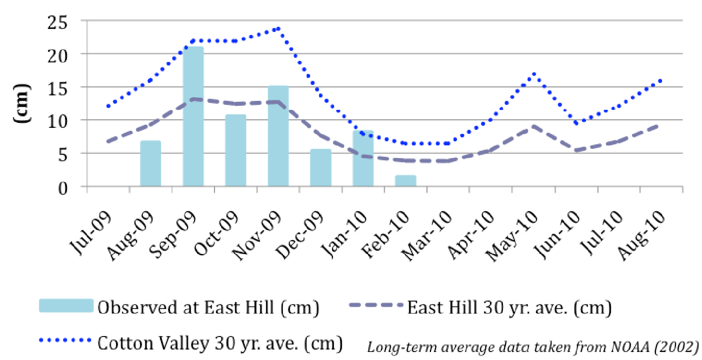

Figure 1 Long term average and observed precipitation for East Hill and Cotton Valley

A total of fifteen sediment traps selected for this study contained representative traps from each of the following three surface types: undisturbed, moderately-to-well vegetated hillslopes (Figure 2a); undisturbed, but poorly vegetated surfaces in the proximity of cliffs (Figure 2b); and eroding foot trails leading down to the bays (Figure 2c). After sediment accumulated in the traps, the mass of material was weighed in the field with a dial scale to the nearest 0.5 lb. Sub-samples of the accumulated material were taken to the lab for moisture content analyses (Gardner, 1986) to correct the field-weighed mass into a dry-weight. Particle-size analyses, based on the dry sieving method, were also performed. Average erosion rates were normalized and calculated for each trap by dividing the ratio of the total sediment production (kg) and source area (m^2) by the total length of the study period (yr), resulting in units of kg m^{-2} yr^{-1}.

Figure 2. Representative sediment traps by surface type: a. vegetated hillslopes, b. cliffs and c. trail surfaces

Laboratory Component:

Subsamples obtained from the sediment traps were partitioned into a coarse and fine fraction by particle size using a 2-mm sieve. The separated subsamples were analyzed in the lab using the Loss on Ignition method to quantify the percent of particulate organic material present in each sample.

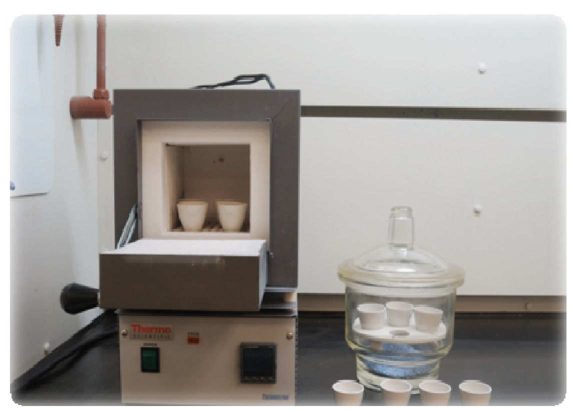

Figure 3 Muffle furnace used for LOI_{550} analysis

The organic material content was determined using a modified Loss on Ignition (LOI) method to determine the percent loss of organic carbon (%POC) (Santisteban, et al., 2004).

The coarse and fine sub-samples were weighed and then placed in an oven at 105°C in a pre-weighed ceramic crucible for 12-24 hours. After cooling to room temperature inside a dessicator, the sample and crucible were weighed again to determine the LOI_{105}.

The Loss on Ignition at 105°C (LOI_{105}) was calculated as:

$$LOI_{105} = \frac{100(WS - DW_{105})}{WS}$$

where WS is the weight of the air-dried sample, in grams and DW_{105} is the dry weight of the sample, in grams, heated at 105°C.

The LOI_{105} sample was then placed in a muffle furnace and heated to 550°C for 4 hours (Figure 2). After cooling to room temperature, the sample was weighed again. The calculated LOI_{550} was the organic material content of the sample. The Loss on Ignition at 550°C was calculated as:

$$LOI_{550} = \frac{100(DW_{105} - DW_{550})}{WS}$$

where LOI_{550} is the percentage of loss on ignition at 550°C and DW_{550} is the weight of the sample, in grams, after heating at 550°C.

The total organic content was calculated as:

$$\text{Coarse Organics, g} = \frac{(\text{Total Sediment in Trap, g})(\%> 2\text{mm})(\%\text{Organics in} >2 \text{ mm Sub-sample})}{10{,}000}$$

$$\text{Fine Organics, g} = \frac{(\text{Total Sediment in Trap, g})(\%< 2\text{mm})(\%\text{Organics in} <2 \text{ mm Sub-sample})}{10{,}000}$$

$$\%\text{Total Organic Content} = \frac{100(\text{Coarse organics, g} + \text{Fine organics, g})}{\text{Total Sediment in Trap}}$$

PRINCIPAL FINDINGS AND SIGNIFICANCE

Vegetation cover seemed to be the greatest factor controlling erosion rates in the study areas on the East End of St. Croix, USVI. Furthermore, surface types that exhibited increased erosion rates (trail and cliff surfaces) also exhibited significant decreased particulate material content, relative to undisturbed surfaces.

Erosion Rates by Surface Type:
On East End Bay watershed, total average erosion rates were highest for cliff surfaces (0.776 kg m^{-2} yr^{-1}) and least among vegetated hillslopes (0.0964 kg m^{-2} yr^{-1}). Average trail surface erosion rates were found to be 0.222 kg m^{-2} yr^{-1} (Figure 4).

Results showed that in East End Bay, cliff and hillslope surfaces had almost identical averaged slopes of 44%, yet cliff surface erosion rates were 78 times higher than undisturbed hillslope surfaces. Slopes for undisturbed hillslope surfaces (44%) were 2.6 times steeper than trail surfaces (17%), though trail surfaces had 22 times higher erosion rates (Reale-Munroe, et. al., 2011).

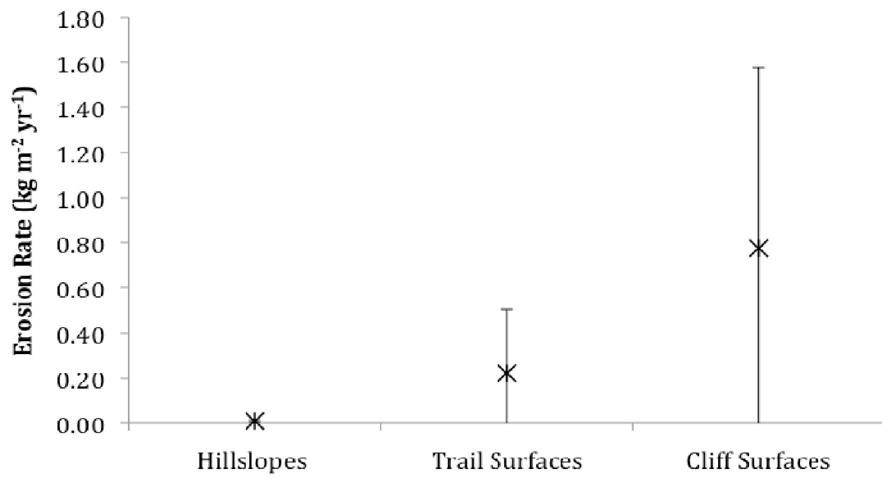

Figure 4 Total average erosion rates by surface type

Particulate Organic Material by Surface Type:

The total particulate organic material found in samples taken from undisturbed hillslope, trail, and cliff surfaces exhibited a decreasing trend relative to erosion rates with %POC values of 12.5%, 4.96% and 3.37%, respectively (Figure 5).

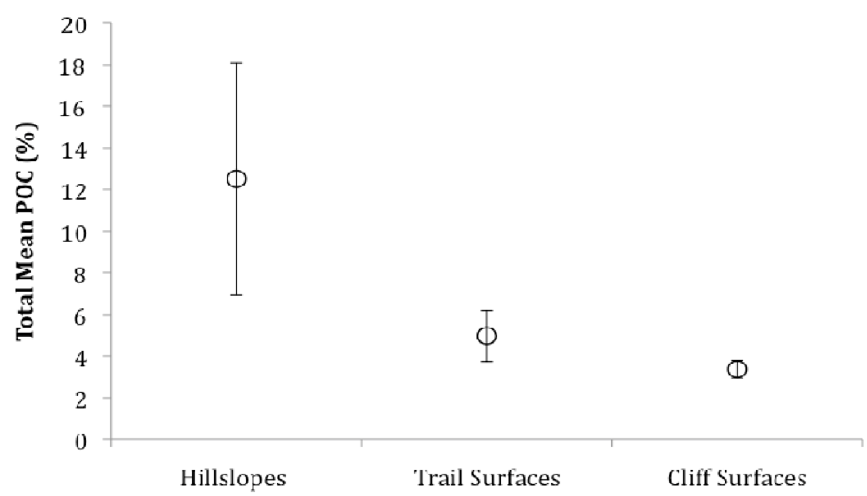

Figure 5 Total mean particulate organic material found in samples by surface type

Erosion Rates by Vegetation Cover:

An inverse, non-linear correlative relationship was exhibited between vegetation cover and average erosion rates (Figure 6). Data seemed to indicate that surfaces with < 45% vegetation cover experienced significantly increased erosion rates. Furthermore, our data suggested that vegetation cover played a first-order role in controlling erosion rates, regardless of surface type. Interestingly, vegetation cover has been shown to play a similar dominating role with a non-linear expression in erosion rates in a similar sub-tropical dry climatic setting in Southwestern Puerto Rico (Ramos-Scharrón, 2010).

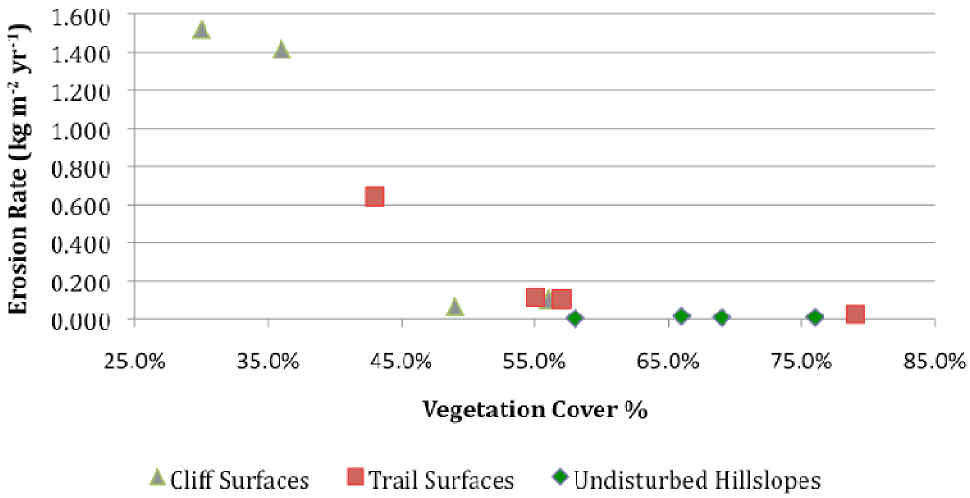

Figure 6 Erosion rates by surface types and % vegetation cover

Particulate Organic Material by Vegetation Cover:

A positive, non-linear correlation was observed between %POC and vegetation cover, particularly among undisturbed hillslope surfaces (Figure 7). However, even with high vegetation cover, samples taken from trail surfaces exhibited low %POC. Perhaps, this was because the mass ratio between organic material and sediment was not significant enough to be detected with total averaged % POC values.

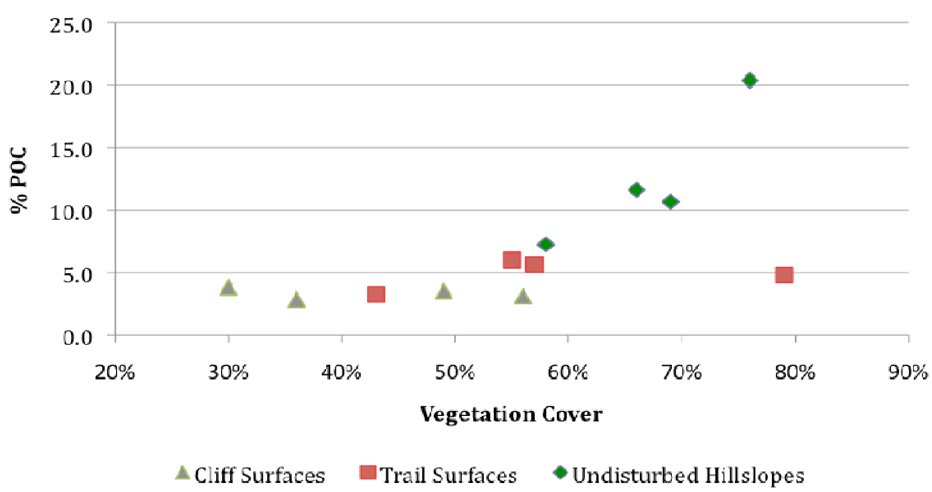

Figure 7 %POC by surface type and vegetation cover

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Water Usage in Flood and Drip Irrigation of Rice Production in the U.S. Virgin Islands

Basic Information

Title:	Water Usage in Flood and Drip Irrigation of Rice Production in the U.S. Virgin Islands
Project Number:	2010VI172B
Start Date:	3/1/2010
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Congressional District:	VI
Research Category:	Biological Sciences
Focus Category:	Agriculture, Irrigation, Water Use
Descriptors:	None
Principal Investigators:	Thomas W. Zimmerman

Publications

1. Zimmerman, T.W. 2011, Evaluation of Irrigation Systems for Rice Production on St. Croix, USVI, in Proceedings 46th Caribbean Food Crops Society, July 11-17, 2010, Boca Chica, Dominican Republic. 46:(in press).
2. Zimmerman, Thomas, 2011, Evaluation of Irrigation Systems for Rice Production on St. Croix, USVI, Virgin Islands Water Resources Research Institute, University of the Virgin Islands, St. Thomas, U. S. Virgin Islands, 8 pages.

PROBLEM AND RESEARCH OBJECTIVES

The potential for rice production on St. Croix is limited in that research is needed to justify engaging in rice farming. There is no information on either rice production in the US Virgin Islands or use of irrigation method of flood or drip in rice production. The fact that the US Virgin Islands are in the tropics makes it a convenient site for rice production that could yield two or even three crops a year with improved early cultivars. Land on the western end of St. Croix is flat flood plain with a San Anton clay loam (USDA-SCS, 1970) with wells present as a water source.

The crop farms in the U.S. Virgin Islands are mainly comprised of small farmers. The average amount of land for a crop farmer is 3.4 acres (National Agricultural Statistics, 2009). The small size limits the investment farmer can make to produce a crop. There has to be a strong benefit of a technology before a farmer will invest in it and adapt it to their farming practices. Drip irrigation is a technology for the efficient application of water but requires a costly investment. Water is most often the limiting factor to crop production in the U.S. Virgin Islands. The municipal source of water is from desalination of seawater. Due to the cost of the desalinated municipal water, farmers use the water sparingly. However, through the use of more efficient water utilization, as obtained through drip irrigation, the potential exists that crop production can result in economical gains for the local farmers.

The objective of this study was to investigate and establish proficient ways for farmers to manage water usage during rice production. By establishing the beneficial influence of drip irrigation, applying the irrigation technology to the situation and incorporating sustainable production practices, water conservation and improve soil stewardship could be achievable. The benefit to the small scale minority farmer would not only be the use of environmentally sound farming practices but also increased real income from production.

METHODOLOGY

Rice was in at the start of the dry season that extends from December to May. During this period, the vapor pressure deficit increase due to prevalent winds. All crops were sown in dry soil at a rate of 45 lb/acre. Four rice cultivars, ‘Bengal’, ‘Cybonnet’, ‘Neptune’ and ‘Taipei’ were grown in small plots on the western end of St Croix.

Four row plots at 25’ with 10” between rows were seeded of each of the four rice cultivars. Pre-emergent herbicide was applied after planting. Drip tape irrigation with one foot emitters was installed after planting at the density of one line per two rice rows, 20”. The drip tape had a low flow rate of 20 gal/hour per 100 ft. Chemical and manual weed control was used. Pre-emergent herbicide was applied when the seed sowing was completed and prior to the installation of the drip lines to control damage from driving over them. Nitrogen fertilizer was applied in 3 splits for a total application of 110 lb/acre. Basal Phosphorus and Potassium were applied at 30 lb/acre. Fertilizer rates were based on soil analysis conducted by Waters Agricultural Labs Inc. and their recommended rates for rice production. The first fertilization incorporated a 20-20-20 complete fertilizer with micronutrients was applied three weeks after planting. During the fourth week, ammonium sulfate was applied. The final fertilizer applied was urea during the fifth week. All fertilizer was dissolved and injected into the main drip irrigation lines with a Dosmatic injector. Irrigation was provided by drip irrigation at the initiation for all treatments until the fertilizer was applied. Irrigation water was applied to maintain soil water potential above −0.04 MPa (monitored using tensiometers at a six inch depth), which is the level at which more sensitive rice cultivars begin to exhibit a reduction in relative transpiration (Bois et al., 1984). The basic stand establishment was recorded at two weeks and tillering at six weeks by a prebaccalaureate student. A levee was constructed with student assistance, after the fertilizer was applied, enclosing a 30 ft square section of the rice plot for flood irrigation. Harvesting consisted of 20 ft sections of the central two rows for each variety and replicated three times for the drip area and once for the flooded section. Harvested rice was threshed, cleaned and dried to 12% moisture content.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Findings

No difference was observed in the growth, plant height date to anthesis or maturity within a variety between the two irrigation systems. ‘Cybonnet’ was a shorter and earlier variety to flower and set seed. ‘Cybonnet’ had more commonly empty panicles that could have been due to the application of herbicide late in its development. Because the ‘Cybonnet’ was under constant irrigation as it matured, it was continually developing tillers and panicles. This resulted in panicles of differing maturity at harvest. At the time of harvest, there was shattering of some ‘Cybonnet’ seed which may have reduced the overall yield data for this variety. Both ‘Bengal’ and ‘Neptune’ were of similar height but ‘Bengal’ had the greatest yield of all varieties and treatments in the flooded plot with 3,720 lb/acre. Both ‘Cybonnet’ and ‘Neptune’ had greater yield with drip irrigation as compared to flooding.

Conclusions and Recommendations

Rice production is possible during the dry season on St. Croix, USVI with drip irrigation and can produce yields for ‘Cybonnet’ and ‘Neptune’ that are similar or better than flood irrigation. However, the variety ‘Bengal’ produced more rice under the flooded paddy system then the drip irrigation. Drip irrigation was able to keep the field saturated with water and allowed even application of fertilizer through an injector. Drip irrigation used 1.04 acre feet less water than flooded paddy system. Rice can be success fully grown in the Virgin Islands with drip irrigation and have yields comparable to a flooded paddy system. The farmer will have to balance the cost of the water as compared to the cost of the drip irrigation system to determine if either is economically feasible in the US Virgin Islands for rice production. Using the natural rainfall by planting the rice prior to the rainy season may have potential to further limit the use of water for rice production.

Plant Height and Yield of Three Rice Varieties Grown Under Drip Irrigation or Flooding on St. Croix, USVI.			
Variety	Height *(cm)*	Drip *(lbs./acre)*	Flood *(lbs./acre)*
Cybonnet	38.9	2565	2015
Bengal	51.8	3505	3720
Neptune	55.1	3240	2930

Influence of the Atlantic warm pool on the climate of the Lesser Antilles

Basic Information

Title:	Influence of the Atlantic warm pool on the climate of the Lesser Antilles
Project Number:	2010VI174B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	FL 02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, None, None
Descriptors:	None
Principal Investigators:	Vasubandhu Misra, Henry H. Smith

Publications

1. Chan, S. C., V. Misra, and H. Smith (2011), A modeling study of the interaction between the Atlantic Warm Pool, the tropical Atlantic easterlies, and the Lesser Antilles, J. Geophys. Res., 116, D00Q02, doi:10.1029/2010JD015260.
2. Misra, Vasubandhu, 2011, Influence of the Atlantic Warm Pool on the Climate of the Lesser Antilles, Virgin Islands Water Resources Research Institute, University of the Virgin Islands, St. Thomas, U. S. Virgin Islands, 32 pages.

PROBLEM AND RESEARCH OBJECTIVES

The sustainability of a society and in this context of island nations is critically dependent on the fresh water availability. A significant source of the fresh water in these islands comes from precipitation. In this research we propose to study the rainfall variability of the Lesser Antilles in the late boreal summer-early fall (August-September-October [ASO]) season. Since most of the current global climate models are so coarse in horizontal resolution that these islands of the Lesser Antilles are not even resolved. As a result the interpretation of the predictions of say interannual variations of rainfall, surface temperature over these islands are based on the large-scale variations. There is however reason to speculate that there could be some local feedback mechanism such as that of the land-atmosphere interactions, or the influence of local orography that may influence the local climate, unresolved in the global climate models. This mechanistic study offers to first understand the role of the interannual variations of the surrounding oceans on the rainfall variations of the Lesser Antilles. This could lead to a possible insight to the behavior of the ASO rainfall in the Lesser Antilles in a warming climate. The Intra-Americas Seas (IAS), which includes the Caribbean Sea and the Gulf of Mexico, is at the seat of a new Climate Variability-Variability of the American Monsoon System (CLIVAR-VAMOS) initiative called the Intra-Americas Sea Climate Program (IASCLIP; http://www.eol.ucar.edu/projects/iasclip/documentation/IASCLIP_feb05.pdf).

The rationale for such an initiative stems from the recognition that the IAS hosts the second largest body of very warm SST ($\geq 28.5^0$C) in the boreal summer-fall season, after the warm pool region in the western Pacific Ocean (Wang and Enfield 2001). This Western Hemisphere Warm Pool (WHWP) extends over parts of the tropical eastern North Pacific (ENP) and into the IAS region called the AWP. The area of ENP is comparably much smaller than the AWP, and thereby the WHWP as a whole is more strongly influenced by the AWP (Wang et al. 2008). The AWP area undergoes significant interannual variations, which influences the warm season precipitation over the Caribbean, Mexico, Central America, southeast Pacific, northwest US and the Great Plains region (Wang et al. 2006). While most climate prediction models have large bias in terms of summer season precipitation over the IAS region (Chen et al. 1999), the AWP is a potential source for boreal summer-fall (ASO) season rainfall predictability.

The overarching objectives of this project are:

1. To discern the influence of the interannual variations of the AWP on the corresponding interannual rainfall variations over the Lesser Antilles
2. To examine the influence of the AWP on the diurnal variations of the Lesser Antilles
3. To asses the impact on the precipitation over the Lesser Antilles from AWP variations

Because of the small size of some of the Caribbean islands (especially in the Lesser Antilles), most global climate models simply cannot resolve the islands. Here we seek to understand:

1) The islands impact on the regional climate
2) The AWP/CLLJ variability modulation of the islands' climate variability

This is accomplished with a dynamical model where the relatively small islands are explicitly resolved. In the few attempts to conduct such model simulations for the region, Amador (2008) shows reanalyses downscaling improves the representation lower-troposphere winds. Here we chose the National Centers for Environmental Prediction (NCEP)-Scripps Institution of Oceanography (SIO) Regional Spectral Model (RSM; Juang and Kanamitsu 1994).

The only medium that the island can interact with the surrounding water is through the atmosphere. The interaction of the prevailing low-level easterlies with the islands may occur at the mesoscale through the island's geography and diurnal variations. The heating-forced convective mixing (Holton 2004), sea/land breezes caused by temperature contrasts, and the drag on the atmospheric flow from the island's topography and land cover (Smith et al., 1997; Carbone et al., 2000) are examples of possible interactions.

Focusing only on topography interaction, Grubišić et al. (1995) and Smith et al. (1997) have shown that the island shapes have an impact of the wake generated. In the RSM, the Lesser Antilles has less topography than in reality (see Fig. 1, and compare with Smith et al. [1997]); however, it is a major improvement from having no islands at all in the coarse grid models.

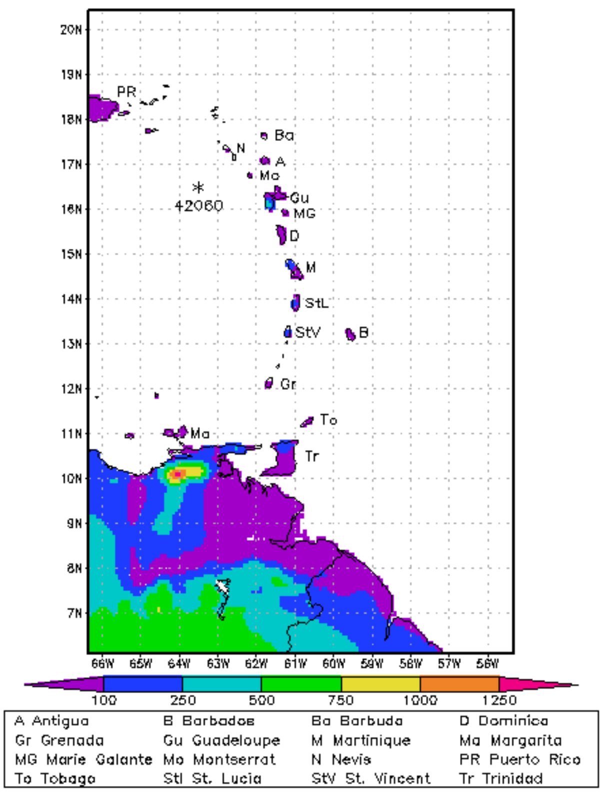

Fig. 1: The domain used in the regional climate simulation. Major islands and surface topography are shown. National Data Buoy Center 42060's coordinate is marked with a "".*

METHODOLOGY

In the absence of any reliable source of observed data or atmospheric reanalysis for the Lesser Antilles, we propose to conduct a regional downscaling study using a regional climate model at very high atmospheric resolution, approximately at 8km resolution that resolves the Lesser Antilles (Fig. 1) to investigate the issues enlisted in the previous section. We intend to use the Regional Spectral Model (RSM) as our regional climate model that was originally developed at the National Centers for Environmental Prediction

(NCEP; Juang and Kanamitsu 1994) and now maintained at the Experimental Climate Prediction Center (ECPC) at University of California San Diego (UCSD; Kanamaru and Kanamitsu 2007).

RSM simulations are carried out at 8-km horizontal resolution with a 20-second time step and 28 vertical sigma-pressure levels. Upper atmosphere and single layer (including 2-meter temperature) outputs are available at three-hour and one-hour intervals, respectively. The simulation domain is shown in Figure 1. The domain covers the eastern Caribbean, the Lesser Antilles, and parts of South America and the Greater Antilles. The islands are relatively flat compared to continental South America; only Guadeloupe has “surface topography” higher than 250 m. The core of the CLLJ is located at the west end of the domain, and our domain includes up to the eastern LLJ entrance (see Fig. 1).We made 10 integrations of month long duration at 8km horizontal resolution over the domain shown in Fig. 1 below using the ECPC Regional Spectral Model (RSM; Kanamaru and Kanamitsu 2007). The RSM is forced with the NCEP-DOE reanalysis (Kanamitsu et al. 2002) at the lateral boundaries. These month long integrations are conducted for August for 5 biggest Atlantic Warm Pool (AWP) years and 5 smallest AWP years.

PRINCIPAL FINDINGS AND SIGNIFICANCE

***RSM simulation of regional climate*:** August AWP areas are highly correlated (0.8+; not shown) with both JJA and ASO seasonal AWP areas. Therefore, August is representative

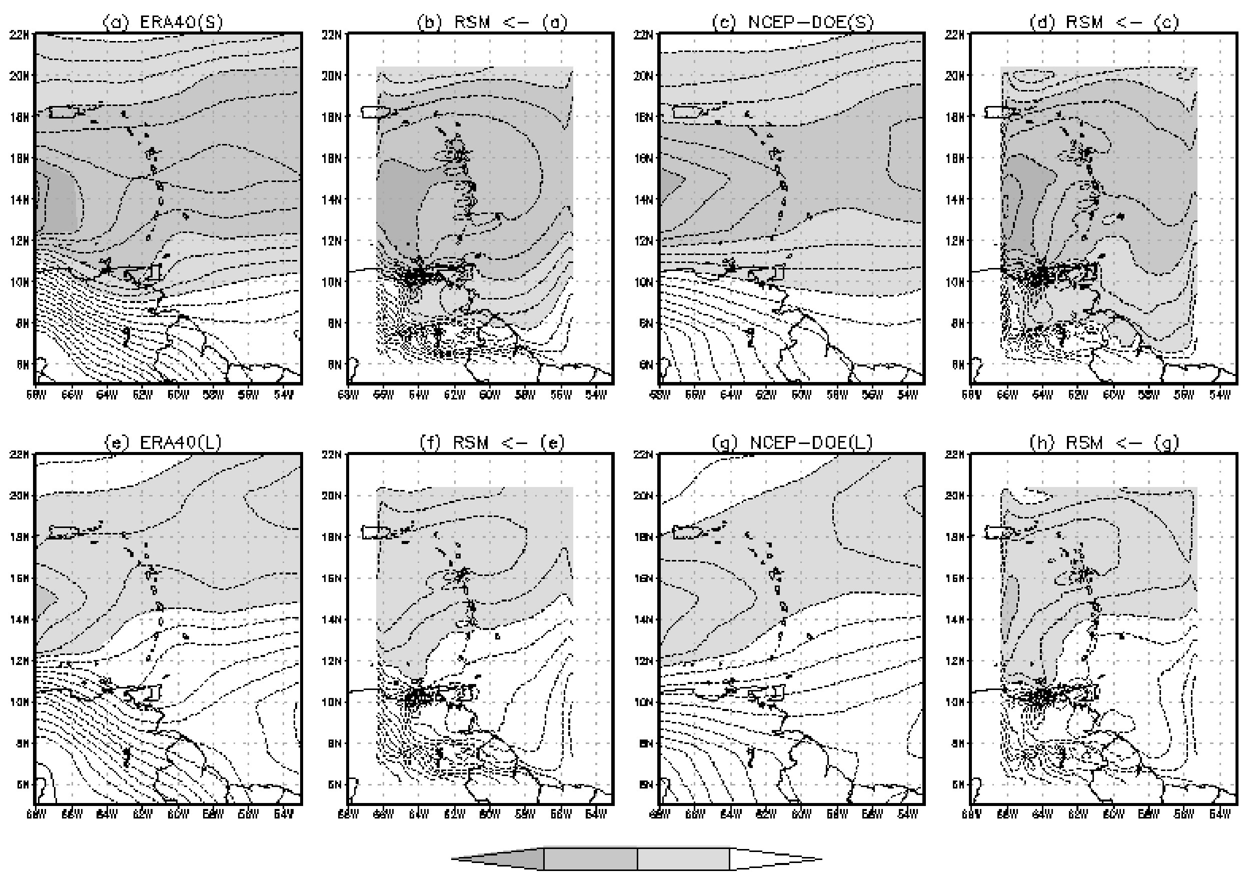

Figure 2: The reanalyses and their RSM downscaled U_{925} for the selected small (upper row; 1984, 1986, 1994, and 1992) and large AWP (lower row; 1998, 1999, 1987, and 1995) Augusts. The reanalyses are plotted in panels a, c, e, and g, and their downscalings are in panels b, d, f, and h. Contours intervals are 0.5 ms^{-1}.

month for downscaling. The prescribed ERA SST differences between the large and small AWP Augusts in our domain are about 1°C lower in the selected small AWP Augusts. The ERA SST differences decrease both northward and southward away from the Lesser Antilles. Reanalyses and their regional simulations generally share similar features. Large AWP Augusts have weaker low-level easterlies across the simulation domain. The easterlies are weaker across the Lesser Antilles; stronger easterlies are evident in the open Atlantic to the east and the CLLJ core to the west.. RSM-simulated easterlies are weaker in the immediate vicinity and to the west of the islands, and mesoscale easterly maximums are evident between the Lesser Antilles islands (Figure 2). Such features are absent in Fig. 2 in both global reanalyses, which is not surprising given the coarse model resolutions: NCEP Global Forecast System (GFS) T62 (~180 km), ECMWF ERA-40 T159 (~100km. Terrain-flow interactions in the RSM simulations are evident in northeastern Venezuela.

There are enhanced 925-hPa easterlies on the southern flanks of elevated terrain where a LLJ has been observed (Douglas et al., 2005). The downscaled and reanalyses easterlies across the islands are not only stronger, but also more uniform during the small AWP years. With the exception of Trinidad, 925-hPa easterlies in the RSM simulations and ERA-40 are uniformly 9-9.5 ms^{-1} across all of the Lesser Antilles. For the large AWP RSM simulations, 8+ ms^{-1} easterlies can be found only near the northern end of the Lesser Antilles (Leeward Islands). Over the southern end of the island chain (Windward Islands), 925-hPa easterlies weaken to ~6.5 ms^{-1} during large AWP years.

***Interaction between AWP interannual variations and island diurnal variability*:** The simulated interannual variability of the island's diurnal variability is dependent on the size of the island. AWP variability can influence the islands' climate by modulating tropical cyclone activities [Wang and Lee, 2007]. Because of our experimental design (prescribed daily mean SST) and the lack of diurnal variability over the ocean, the AWP interannual variability of two-meter air temperature (T_{2m}) and winds over water is most pronounced by the shift of the daily average. Over the islands, both daily maximum and minimum T_{2m} are increased during the large AWP Augusts; however, the change of daily T_{2m} maximum at interannual scales is clearly larger than the daily T_{2m} minimum.

The interannual variability of the daily T_{2m} maximum over all individual islands is larger than the interannual variability of the daily T_{2m} minimum. The average change between large and small AWP of the maximum, minimum, and daily average T_{2m} over the islands, however, is approximately the same regardless of whether this averaging is performed per area or per island. But the actual values of the maximum and minimum T_{2m} are dependent on the averaging method. Averaging per island reduces diurnal temperature range ΔT_{2m}. The interannual variability of daily average T_{2m} over the islands is smaller than the simulated values over water. The T_{2m} variability over water itself is weaker than the variability of the prescribed diurnally invariant daily average SST. The prescribed SST differences between large and small AWP Augusts are at least 0.9°C around the Lesser Antilles.

***Precipitation changes and sensitivities to forcing reanalyses*:** The relationship between Caribbean rainfall anomalies and AWP variability is well understood (Wang 2007). The precipitation differences between the large and small AWP Augusts may not be very surprising; naturally, warmer SST (larger AWP) will lead to increased precipitation. What may be of more interest are the differences between the reanalyses and the sensitivity of

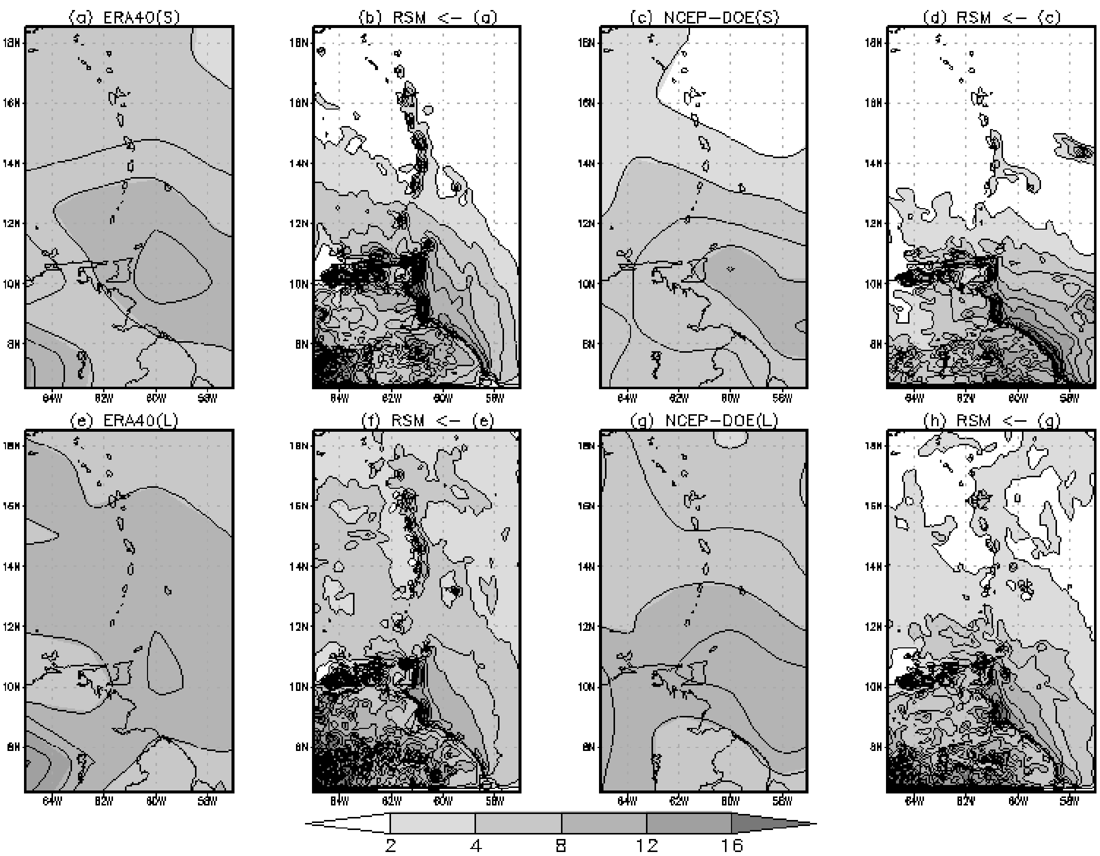

Figure 3: Mean August precipitation (mm/day) for small AWP years (mm/day) from a) ERA-40, b) ERA-40 downscaled by RSM, c) R2, and d) R2 downscaled by RSM. Corresponding figures for large AWP Augusts are shown in the lower panels.

the RSM simulation to the forcing reanalyses. August is during the height of Central America mid-summer drought, but such drought as not as evident in the eastern Caribbean [Magaña et al., 1999; Amador, 2008]. The composite August RSM and reanalyses precipitations are shown in Figure 3. As expected, rainfall is decreased for the small AWP Augusts (top panels of Figure 3) for both reanalyses and RSM simulations; the differences between the large and small AWP simulations are most noticeable on the Leeward Islands.

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Information Transfer Program Introduction

As the only unit in the U. S. Virgin Islands having a primary mission of conducting water resources research, dissemination of research findings is an important component of the work of the Virgin Islands Water Resources Research Institute. The islands of the USVI, being separated from each other by water, adds special challenges in many ways similar to the disseminating of information to and from our similarly situated neighbors in the Caribbean basin, those elsewhere in Oceania around the world whose water issues are similar to those in the USVI and collaborators on the U. S. mainland.

This year the VI-WRRI engaged in a student centered project of scanning and uploading all VI-WRRI publications that could be located and making them accessible through its web page. This represented a major departure from the previous practice of manually processing requests for documents and has significantly changed the information dissemination process for the VI-WRRI.

In addition to requiring that all research projects include a project completion report, there was one project in FY 2010 dedicated entirely to facilitation of exchange of information on water resources issues particularly relevant to tropical islands. This was the eight in the series of Caribbean Islands Water Resources Congresses which started as a collaborative effort between the VI-WRRI, the Puerto Rico WRRI and the then Caribbean District Office of the USGS in 1984. A summary of that effort follows.

The Eighth Caribbean Islands Water Resources Congress

Basic Information

Title:	The Eighth Caribbean Islands Water Resources Congress
Project Number:	2010VI175B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	NA
Research Category:	Not Applicable
Focus Category:	Education, Hydrology, Management and Planning
Descriptors:	None
Principal Investigators:	Henry H. Smith

Publication

1. Frias, Rafael E. (Guest Associate Editor), Water Resources Impact, 2010, Volume 12, Number 4, American Water Resources Association, 20 pages.

PROBLEM AND INFORMATION DISSEMINATION OBJECTIVES

Successful management of water resources on islands, as elsewhere, often requires skills that are developed in the place of application or through interaction with others who have worked under similar conditions. This might be due to the lack of documentation or data, very small scale issues to which typical solutions are not applicable and geographic and other factors that might be unique to a location.

The U. S. Virgin Islands is an insular region in many ways. This is strinkingly true when it comes to management of its water resources. Due to its geographic isolation, persons working with water resources in the Virgin Islands have less of an opportunity to interact with and learn from the experiences of others. While technology has certainly improved communication between the USVI and elsewhere, there is a high value to meeting with counterparts from other islands and elsewhere to interact, learn of experiences, share knowledge and exchange ideas.

METHODOLOGY

The issues described above are among those that favor conduct of a forum for the exchange of ideas and sharing of experiences among persons working in or having an interest in addressing Caribbean water resources issues. In response to this challenge, in 1984 the Virgin Islands Water Resources Research Institute, the Puerto Rico Water Resources Research Institute and the Caribbean District Office of the Water Resources Division of the U. S. Geological Survey convened the First Caribbean Islands Water Resources Congress in St. Thomas. The success of that first meeting resulted in several follow-up conferences being held in subsequent years. These meetings have been all well-attended and have been held in the U. S. Virgin Islands and Puerto Rico. The seventh meeting was held in St. Croix on October 25 – 26, 2007.

RESULTS

The VI WRRI worked along with the Puerto Rico Water Resources Research Institute, the USGS Caribbean Water Science Center (CWSC) and the American Water Resources Association to convene the "AWRA International Summer Specialty Conference and Eighth Caribbean Islands Water Resources Congress on Tropical Hydrology and Sustainable Water Resources in a Changing Climate". The activity took place from August 30 to September 1, 2010 in San Juan, Puerto Rico.

110 persons registered for this conference and represented professionals and technicians involved in water resources and environmental issues from the private sector, local and federal governments and academia. Abstracts from South America, Central America and Asia were received prior to the conference. However, extreme weather conditions due to the passage of Hurricane Earl at the end of September 2010 made the attendance of

several participants impossible. There were 22 states and several Caribbean islands represented at the conference.

The conference included a keynote presentation by Dr. Matthew C. Larsen, Associate Director for Water with the USGS whose presentation was titled *Status of Our Water Resources - USGS Perspective.* Two panel presentations were also organized on the topics "40 Years of Environmental Regulation – Past, Present and Future" and "Economies of Water, Water and Energy Nexus and Innovative Solutions for Water Resources Management". Two concurrent sessions were conducted during the three-day period for a total of 55 presentations. The sessions were on the topics appearing in the table below.

Topics Covered in the Eight Caribbean Islands Water Resources Congress

Groundwater Quality	Río de la Plata Flood Control Project
Computer Modeling	Hydrologic Processes
Hydrometeorology	Water Resources in a Changing Climate
Water Management	Watershed Modeling
Flood Warning Systems	Sustainable Water Resources
Surface Water Runoff Modeling	Water Distribution Management
Managing the Environment	Flooding and Stormwater Management

The conference provided the opportunity for discussion of these and other areas of interests among persons including:

- Managers, scientists, practitioners, modelers, educators and students
- Hydrologists, engineers, ecologists, biologists, physical scientists
- Local, regional and federal government agencies and non-governmental agencies, members of water-related agencies, watershed groups, environmental stakeholders and NGOs

Among the many benefits realized through convening the meeting were:

- Development of practitioners' personal familiarity with counterparts and their roles and responsibilities
- Gain of knowledge of resources that may be available from other persons and agencies in the Caribbean
- Development and implementation of mechanisms for cooperation and collaboration in the region
- Enrichment of skills and knowledge through discussion of ideas and experiences with others working in similar situations.

Besides being an excellent opportunity to strengthen relations among professionals from different locations it also produced a high quality publication. An electronic version of the conference program is available at http://www.awra.org/meetings/PR2010/. Additionally, an issue of the American Water Resources Association's magazine, *IMPACT,* was dedicated exclusively to the conference's topics. The presentations were indicative of the needs and the efforts been made to improve the situation of the water resources in the tropics and provided a basis for future research towards their sustainability under changing climate conditions. Finally, attractive exhibitions from manufacturers and service providers provided conference attendees with state-of-the-art information on equipment and technical services available.

It is expected that this series of Caribbean islands water resources congresses will continue well into the future.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	0	0	0	6
Masters	2	0	0	0	2
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	8	0	0	0	8

Notable Awards and Achievements

Publications from Prior Years

1. 2007VI90B ("Response to Uncertain Irrigation Supplies Through Recovery and Application of Aquaculture Wastewater for Agronomic Crops Cultivated in the U.S. Virgin Islands.") - Other Publications - Danaher, Jason, 2009, Evaluating Geotextile Technology to Enhance Sustainability of Agricultural Production Systems in the U. S. Virgin Islands, Technical Bulletin #14, Agricultural Experiment Station, University of the Virgin Islands, St. Croix, U. S. Virgin Islands, 2 pages.