Virgin Islands Water Resources Research Institute Annual Technical Report FY 2009

Introduction

The U. S. Virgin Islands are a Territory of the United States. The Territory consists of four principal islands - Water Island, St. John, St. Thomas and St. Croix. The islands are principally of volcanic origin and rely on several sources for their water supply. Ground water is limited due to the steep slopes, limited land area and the islands' geology. Rain water harvesting is required by law and serves as the principal water source in most residences. Desalinated water is available through the public water distribution systems and also is produced and used at many hotels and other commercial establishments. As production of safe and sufficient water is a concern, so too is proper disposal of wastewater.

The Virgin Islands Water Resources Research Institute is hosted by the University of the Virgin Islands (UVI). UVI is a small school with campuses on the islands of St. Thomas and St. Croix and a field research station on St John. It is principally an undergraduate school and is land-grant Historically Black College or University (HBCU). As the only institution of higher learning in the U. S. Virgin Islands, UVI is expected to and does serve a wide variety of needs of the USVI community. While most of its students come from the USVI, a large proportion of the student population comes from other Caribbean islands and also the U. S. mainland. The largest academic program is in Business Administration. UVI has a well known marine science program and recently begun offering a masters degree in this area. UVI is accredited by the Commission of Higher Education of the Middle States Association of Colleges and Schools.

The Virgin Islands Water Resources Research Institute (VI-WRRI) has been at UVI since 1973. It is one of the smaller institutes in the U. S. Geological Survey's State Water Institute Program and relies principally on the USGS for its support. Similarly the Virgin Islands' public relies on the research, training and information dissemination conducted through the auspices of the VI-WRRI to serve their needs which often are specific to small tropical oceanic islands. The VI-WRRI relies on guidance provided by an advisory group consisting of professionals and laypersons, USVI residents and non-residents but all persons committed to contributing to improvement of water supplies for residents of the U. S. Virgin Islands.

Research Program Introduction

Research projects reported on in this annual report include those that were not reported in last year's report as completed and those that were funded for execution in the FY 2009 period. The FY 2009 projects addressed matters having to do with cistern water quality, treatment of wastewater from aquaponic systems and sediment export from watersheds. All projects provide specifically for dissemination of information gained through the research conducted. Training opportunities for students were also provided.

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:	3/1/2008
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Water Quality
Focus Category:	Water Quality, Toxic Substances, Sediments
Descriptors:	
Principal Investigators:	Thomas Archibald, Stanley L. Latesky

Publication

1. This project is not yet completed.

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.

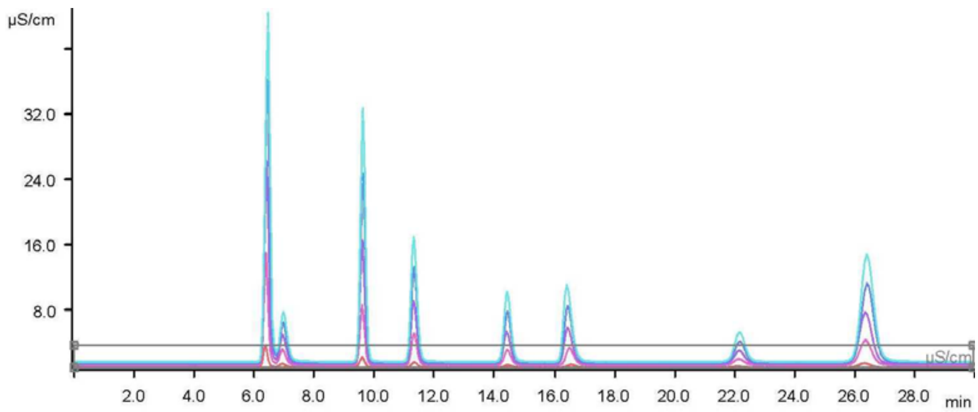
Cation analysis

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.

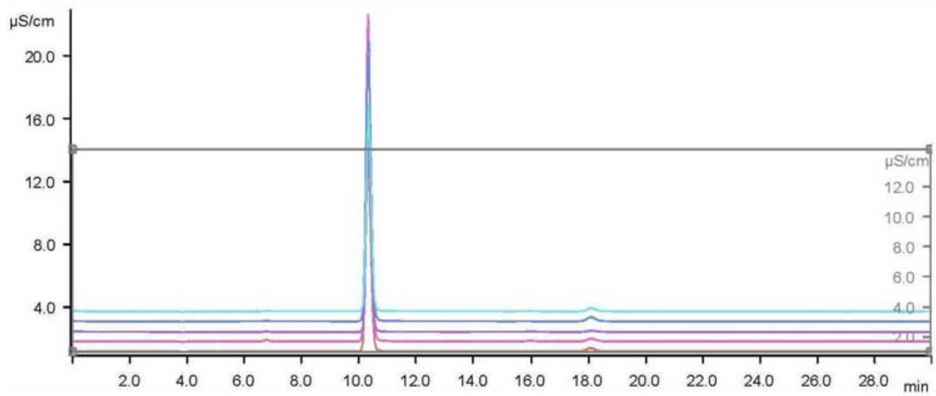


Figure 2: IC for the Water Island samples

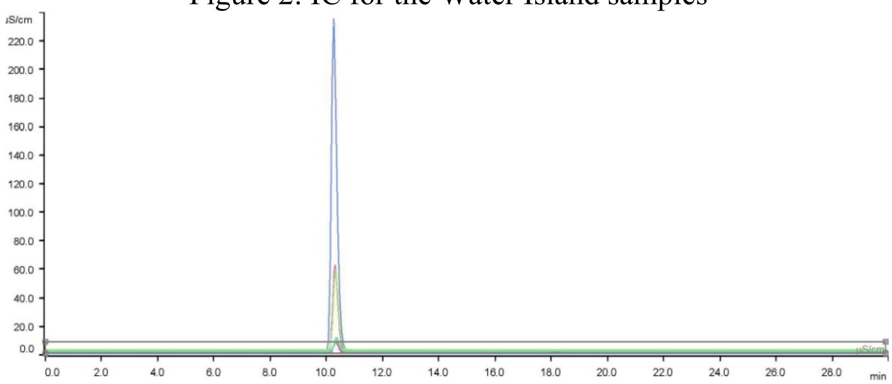


Figure 2: IC for the St. John water samples

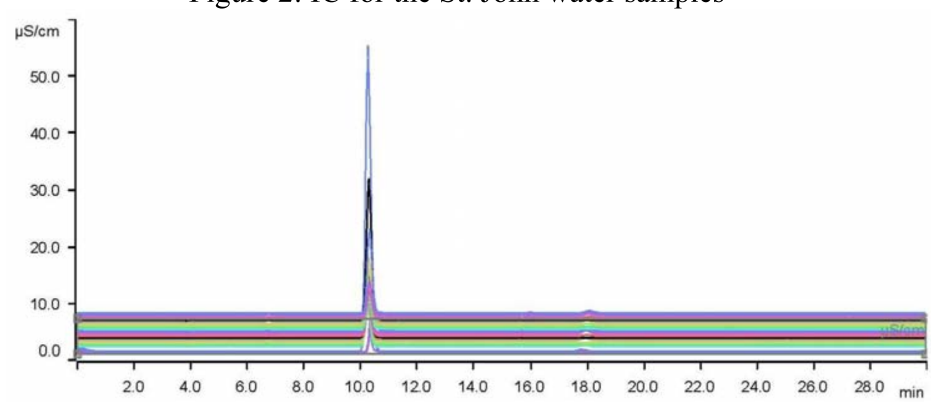


Figure 3: IC for the St. Thomas water samples

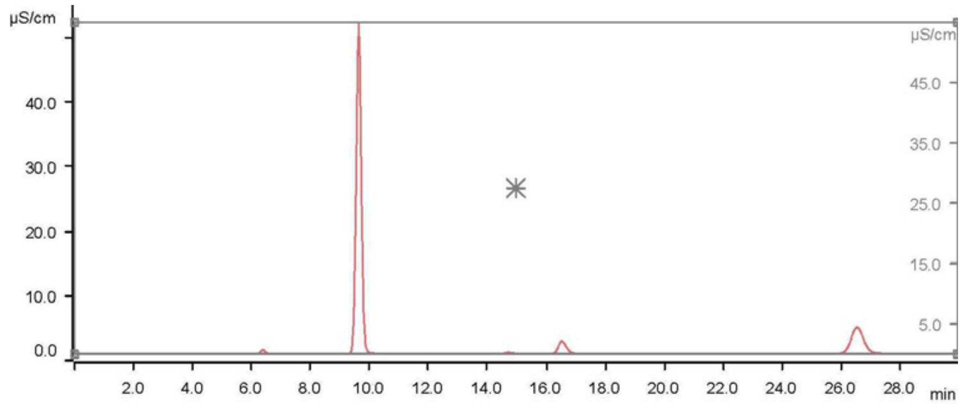


Figure 4: IC for UVI tap water

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.

Use of Wetland Plants to Manage Nitrate Levels in a Biofloc Fish Production System

Basic Information

Title:	Use of Wetland Plants to Manage Nitrate Levels in a Biofloc Fish Production System
Project Number:	2008VI112B
Start Date:	3/1/2008
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Agriculture, Water Quality, Water Use
Descriptors:	
Principal Investigators:	Donald Bailey, Jason James Danaher

Publication

1. No publications have resulted as yet from this project.

PROBLEM AND RESEARCH OBJECTIVES

Maximizing the use of freshwater resources and output from production systems is critical for the future success of agricultural enterprises in the U.S. Virgin Islands. The average rainfall in the region can vary from 400 to 1300 millimeters per year and is concentrated in the wet season (September to November). The U.S. Virgin Islands have only intermittent seasonal streams and freshwater impoundments that frequently dry through evaporation and seepage. Farmers rely on wells or haul water to their field plots for irrigation.

Dual use of the freshwater resource can be achieved by first culturing fish and then applying fish effluent to agronomic crops as irrigation water. The University of the Virgin Islands has developed a commercial biofloc system for the production of tilapia but nitrate-nitrogen accumulates in the system as part of the biological treatment processes. Reducing nitrates to a level where they do not impact fish production nor become a source of groundwater pollution (if applied extensively to agronomic crops) is a desire of farmers incorporating an aquaculture component into their farm enterprise.

The research will determine which of nine wetland plants is best suited for removing nitrate-nitrogen from aquaculture water circulated through denitrification raceways. Reducing nitrate levels to less than 100 mg/l will allow the water to be used extensively on agronomic crops. Farmers will be able to incorporate aquaculture into their farm enterprise and produce additional crops of value. These could include flowers or foliage for sale to florists or a marketable wetland plant for sale to developers mitigating land damage. The results of this study will allow producers to maximize use of their production system without the need to perform undesirable water exchanges to improve water quality

The research will evaluate nine littoral, bog or wetland plants for their growth, production and nitrate removal efficiency in the UVI Aquaculture Program biofloc system denitrifying raceways. The U.S. Virgin Islands have few native freshwater wetland plants due to previous agricultural practices, development and lack of natural freshwater resources. Three have been identified, *Sesuvium portalacastrum*, sea purslane, *Pluchea odorata*, fleabane and *Thalia geniculata*, bent alligator flag (Acevedo-Rodriguez, 2005). These will be cultivated because of their market potential to developers that are required to mitigate wetland damage caused by construction activities. Six other plants have been identified for their use by florists, either for flowers or foliage.

METHODOLOGY

Wetland plants, native and introduced species, will be planted into the denitrification raceways and allowed to establish in blocked areas. The biofloc system will be operated for a six-month period as a fish production trail with daily management including feeding, aeration, sludge removal and pH adjustment. Water quality and plant tissue will be analyzed periodically throughout the fish production trial. Data analysis will determine the absolute decrease in nitrate-nitrogen over the length of the raceways and the rate of nitrate-nitrogen accumulation in the system over the production period.

After the production trial, the fish will be held in the rearing tank and the system managed as a pre-sale holding facility before the fish are marketed. The denitrification raceways will be planted with two species of wetland plant, one species in each raceway. Water quality data analysis will determine the rate of nitrate-nitrogen accumulation and the absolute decrease in nitrate-nitrogen over the length of the raceways. Data on the growth, production and harvest of marketable plant products will be collected and analyzed. An economic analysis of each plant specie will be made to determine the best plant for inclusion in the biofloc system.

PRINCIPAL FINDINGS AND SIGNIFICANCE

TRIAL #1

The biofloc aquaculture system is being used for this research which evaluates the production potential of several wetland plants in raceways using the culture water. The 200-m^3 circular tank was stocked with 5,000 153-g tilapia fingerlings on September 3, 2008. The system also has a 2-m^3 clarifier for removal of fecal solids and other settleable solids, a base addition tank, and 2 raceways for denitrification of the water. Water is pumped through these units with a 1/20th hp circulating pump. The tank water was continuously circulated horizontally with one ¾ hp prop aerator and was aerated with up to 3 vertical aerators.

The fish were reared for 168 days (24 weeks) at which time they were harvested. Final production was 3,711 kgs or 18.55 kg/m^3. During the production period the fish were fed twice each day to apparent satiation for 30 minutes. Digestion and metabolism produce feces and ammonia, NH_3^+. The feces were removed by the clarifier and the raceways. The ammonia was removed by biological processes of nitrifying bacteria in the water column. The end product of nitrification, nitrate-nitrogen (NO_3-N) accumulated in the water. Feces and solids that accumulate in the raceways form anaerobic zones where denitrifying bacteria thrive and can convert nitrate to nitrogen gas. (Figure 1.)

Nine varieties of wetland plants were randomly planted in each raceway. Each variety was planted in a quadrent of 2-m^2 at a density of 4/m^2. These plants were allowed to grow, without tending, by their natural propagation pattern. The two cana lily varieties did not survive. Not all of the other varieties thrived. *Colocasia esculenta*, Green Taro or Dasheen, grew well and produced many plantlets. Final yield was 33.32 kg/m^2. *Cyperus papyrus*, Egyptian papyrus, was the next most productive variety but yielded only half as much plant mass, 16.02 kg/m^2. (Table 1.)

TRIAL #2

In the second phase of this research taro, *C. esculenta*, was planted in one raceway at a density of $4/m^2$ and allowed to grow for 4 months. Dissolved oxygen, pH, ammonia-nitrogen and nitrate-nitrogen water quality parameters were monitored by standard methods biweekly in the rearing tank and at the effluent ends of each raceway. Water quality was also monitored in one raceway with a YSI Multiparameter water quality sonde for a period of three weeks. The sonde recorded hourly pH, ammonium and nitrate values. A UVI student worker was assigned to the maintenance and monitoring of this equipment.

Fourteen (14) plots of 2-m2 each were marked along one trough. Each plot was planted with 8 taro plantlets, (mean wt., 358 g). Over the course of the production period the plants in the first 2 plots died. A gradient of successful growth continued down the trough from plot 3 to 14. Production data for each plot is presented in Table 2.

The influent end of the denitrifying raceway becomes heavily settled with solid waste from the fish production tank. Anaerobic conditions that are desired and encouraged for nitrate removal also produce undesirable byproducts including methane and hydrogen sulfide gas. These byproducts were not measured in this research but it is speculated that they had a detrimental effect on the taro planted in the influent area. Further along the trough solids continued to accumulate did not entrap the roots and corms of the plants.

Nitrate levels in the fish production tank need to be maintained below 500 mg/l for optimum production. This is achieved by the anaerobic conditions in the raceway (Figure 2). Continuous removal of nitrate through the denitrification process dilutes the nitrate-nitrogen level in the rearing tank.

Taro can also remove nitrate by direct uptake through the roots and incorporation into the plant material. Samples of plant material were taken and the tissue analyzed. Nitrogen made up 4.92% of the dry weight of the plant and was typical for herbaceous perennial plants.

The production of edible corms is an additional valuable resource for a farmer. The number of corms increased along the length of the trough (Table 2). The production period for edible corms was not reached so most of the corms were immature and non-marketable. The number of plants that had propagated from the original planting is another indication of potential corm production. Taro corm production can be 9-12 months and is longer than the production period for the tilapia in the rearing tank. This presents production scheduling challenges for farmers integrating tilapia and taro production.

The benefit of anaerobic denitrifying raceways is the removal of nitrate without the need for dilutions with large volumes of water. The raceway appears to have value for the production of a plant crop but several constraints make integration impractical.

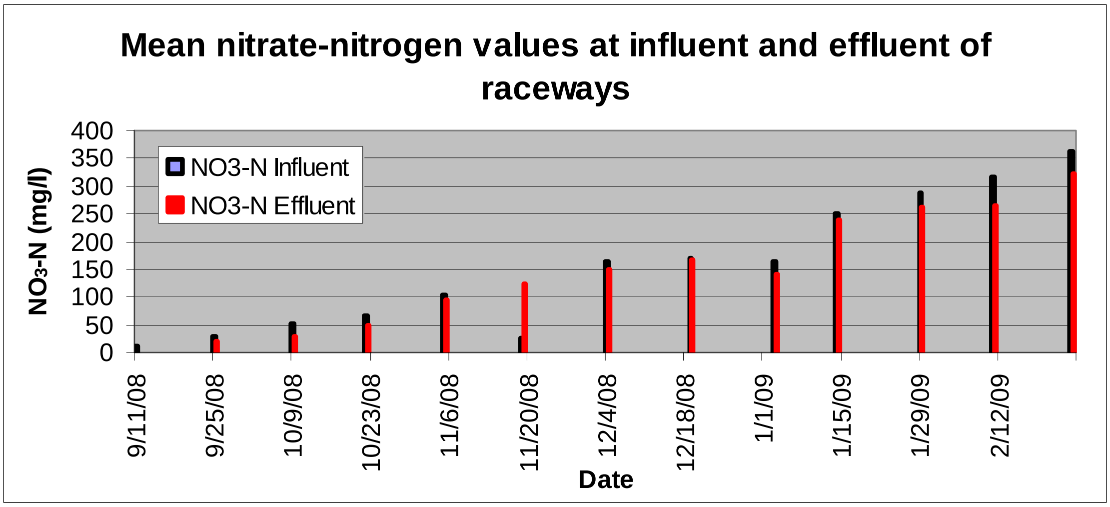


Figure 1. Mean nitrate-nitrogen values show a decline in values from the denitrification occurring in the raceways between the influent and effluent ends.

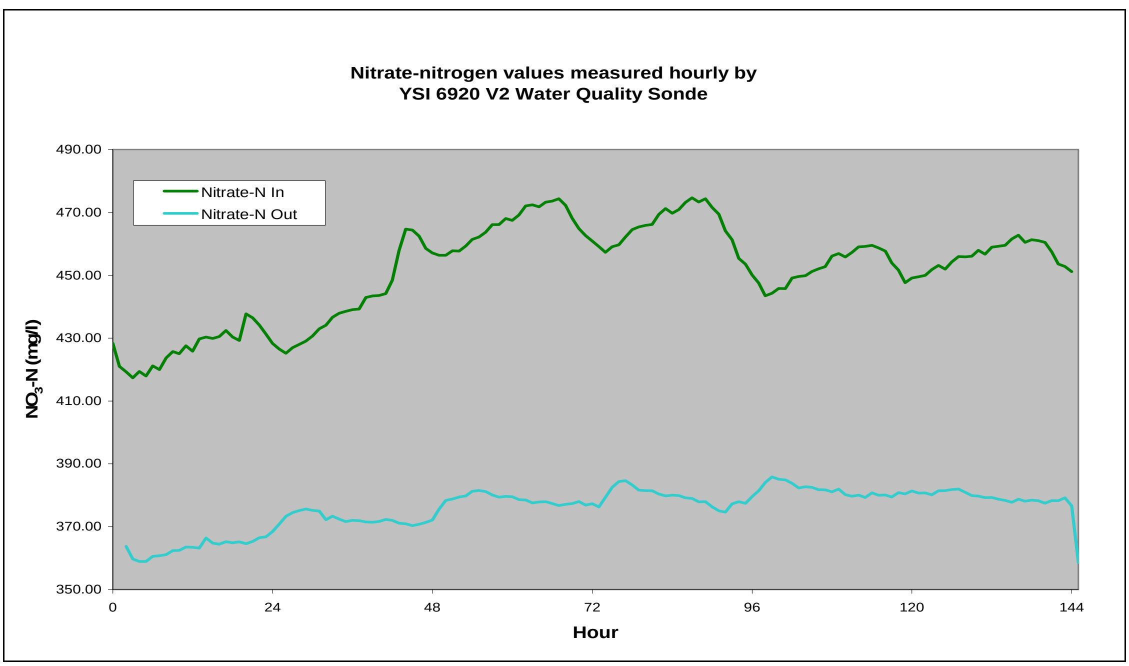


Figure 2. Typical trend of nitrate-nitrogen level of influent and effluent in denitrifying trough used for taro production.

Table 1. Wetland plants grown in denitrifying raceways show a wide range of production.

Latin Name	Common Name	Raceway 1	Raceway 2	Mean kg/m^3
C. esculenta	Green Taro (dasheen)	32.86	33.66	33.26
C. papyrus	Papyrus	18.67	13.361	16.02
S. lancifolia	Giant Sagittaria	6.926	6.034	6.48
I. versicolor	Iris	0.277	0.817	0.55
H. caribaea variegata	Verigated spider lily	0.224	0.338	0.28
C. americanum	Bog lily	0.187	0.162	0.17
T. geniculata	Bent aligator flag	0	1.579	0.79

Table 2.

Position*	Initial Biomass (kgs)	Final Biomass (kgs)	Gain (kgs)	Corms (count)	Corms (kgs)	Corms (mean)	Plant Height (cm)	Plant Count (ea)
1								
2								
3	1.42	0.26	-1.16	9	0.22	0.024	**	**
4	2.65	0.44	-2.21	11	0.38	0.035	**	**
5	2.92	0.60	-2.32	2	0.3	0.150	**	**
6	2.96	1.24	-1.72	4	0.54	0.135	20.17	6
7	3.1	3.84	0.74	5	0.74	0.148	35.75	24
8	2.82	7.98	5.16	31	1.46	0.047	44.78	37
9	2.74	7.48	4.74	16	0.86	0.054	42.42	45
10	4.36	14.30	9.94	49	1.94	0.040	54.93	92
11	3.28	8.40	5.12	24	1.44	0.060	57.87	47
12	1.72	10.04	8.32	53	1.22	0.023	55.94	68
13	3.18	13.20	10.02	66	1.58	0.024	54.57	89
14	3.26	7.52	4.26	84	1.28	0.015	36.01	97

*plants in positions 1-2 had no remaining plant material.
**plants in positions 3-5 had only corms and no vegetative plant material.

A Comparative Analysis of St. Croix Waterways;

Basic Information

Title:	A Comparative Analysis of St. Croix Waterways;
Project Number:	2008VI114B
Start Date:	3/1/2008
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Water Supply, Groundwater, Water Quality
Descriptors:	
Principal Investigators:	Brian Daley

Publications

1. Daley, Brian,Forest, May 2009,Agriculture and Development in a Changing Landscape: Land-cover Change Analysis of St. Croix, USVI using Landsat Satelites from 1992 to 2002, Technical Bulletin #13, Virgin Islands Agricultural Experiment Station, University of the Virgin Islands, St. Croix, U. S. Virgin Islands.
2. Daley, Brian, Tristian Muhammad, Hema Balkaran, June 2009, A Comparative Analysis of Soil Characteristics in St. Croix's Waterways: A Look at the Dirt in our Guts,Student Research Bulletin, Virgin Islands Agricultural Experiment Station, University of the Virgin Islands, St. Croix, U. S. Virgin Islands.

PROBLEM AND RESEARCH OBJECTIVES

The Virgin Islands territory is a dynamic ever-changing landscape. Human land uses such as agriculture and residential development are the primary activities determining land cover of the islands. Land uses that result in the loss of forest cover are frequently associated with subsequent decreases in water quality and negatively affect an aquifer's ability to naturally recharge. Unhealthy waterways exhibit increases in sedimentation, erosion, water speed, water temperature and evaporation. This can result in decreased water quality, lowering water tables and increased costs for the farms and communities that rely on these resources. Over the past two decades the water table in St. Croix has been steadily lowering

There is no known territory-wide health analysis of Virgin Islands' waterways. Within the territory, these natural waterways are referred to as guts. Guts in the Virgin Islands tend to be ephemeral, meaning they are dry for portions of the year. This project will be a preliminary study on how to efficiently accomplish a comprehensive gut health analysis using GIS (Geographic Information Systems) and GPS (Global Positioning System) technology. To this end, findings of a recent AES (Agricultural Experiment Station) land cover change analysis will be combined with field collected data on waterways. By comparing data from forested, deforested and recently reforested waterways, we will be able to describe and quantify the impact various land-uses have on our water resources.

This project will analyze the condition of waterways on St. Croix using state of art GIS and GPS technology. This research project will compare soil and water permeability characteristics from waterways in three distinct land uses. The comparative analysis will be a dynamic combination of field data with current remote sensing research on land cover change in St. Croix between 1992 and 2002. In the process, we will train UVI students to collect field data and provide them with certification in GIS software. Students will present their research in poster format and results will be made available to the community in the form of fact sheets. In keeping with UVI's mission, students will be educated and trained to use this technology during the project.

METHODOLOGY

Students will conduct the ArcGIS 9.2 certification workshop in a UVI computer lab in St. Croix. After the training, we will lead the students in creating digital map layers that delineate the primary waterway or guts in each watershed on St. Croix. The students will create buffers around the guts and then overlay it on a forest cover change layer recently created by UVI-AES. This polygon layer identifies all areas on St. Croix that were deforested or reforested during a recent 10-year period. Students will identify 30 data collection points by intersecting the two layers and choosing 10 points in each category (stable, deforested and reforested) of guts.

Using a Trimble GPS unit we will go to the ten waterways in each category and collect data on forest canopy, land use, topography, and soils characteristics from the USDA-NRCS soils tests. Soils tests will include aggregate stability, water nitrate levels, salinity tests, slake test, and bulk density test. These tests relate to water quality and water movement through the soil indicating what is happening during and after rain events. (Direct sampling of the water in guts can not be done with systematic regularity due to their ephemeral nature.) Some of the tests will be conducted at the UVI-AES lab. When field data collection is completed the students and staff will analyze the data using GIS and statistical methods. The scientific results of this study will be shared with the academic and technical community by archiving the findings with the Virgin Islands Information Council (GIC) and UVI's CDC. The results will be summarized and presented to the Virgin Islands community during a public seminar at the conclusion of the project and also distributed as a fact sheet.

PRINCIPAL ACCOMPLISHMENTS AND SIGNIFICANCE

The results support our original hypothesis that soil in forested sites would have superior characteristics to soil in change areas. Forested guts had the greatest average slope and their banks are significantly steeper than deforested sites (Table 1). Although steep slopes are more prone to erosion, we observed less erosion in the forested sites. Water infiltration rates are influenced by several factors such as soil particle size and soil organic material, but water infiltrated soil in stable forest sites significantly faster than in deforested and reforested sites. Average soil moisture did not differ between sites, with most sites registering on the lowest end of the range. We attribute this to the prolonged dry-period before our sampling and not to an accurate measure of soil organic matter.

Average pH values in deforested sites were significantly higher than in other sites. This is likely due to erosion of pH neutral top-soil leading to exposure of the alkaline sub soils. There was also a trend of soil from forested sites having lower values for, electro-conductivity, temperature, and bulk density. These results are a trend only and did not meet our criteria for statistical significance. Electro-conductivity measurements for forested and reforested fell within the healthy range while deforested sites registered levels that begin to impede plant growth. St. Croix's landscape is highly fragmented and the course of a gut passes through alternating forested and deforested sections.

The conditions at the 30 data collection sites ranged from intact, native forest with deep organic soil, to exposed, treeless sites where the gut was lined with stone (rip-rap) and no soil was present. The original classification of forested, deforested and reforested was completed in 2005. The 10 forested sites were still forested, while four of the reforested sites had recently been cleared and four sites classified as deforested had young patches of secondary forest establishing. These findings emphasize variable and dynamic nature of land-cover change sites.

We conclude that land-cover change in St. Croix is directly linked to the degradation of ephemeral waterways or guts. Degradation in the Virgin Islands can be measured by decreased water infiltration rates and increased pH, bulk density and electro-conductivity. We interpret these results to be a proximal measure of soil compaction and increased run off volume and velocity.

The results from this small-scale pilot study merit additional investigation of the watersheds of the Virgin Islands and the rates, patterns and practices of development in the territory. The first step in this process is to generate a temporal series of classified maps of the U.S Virgin Islands. This can be accomplished using traditional aerial photo interpretation methods, or with increasingly accessible satellite imagery.

Soil and water sampling on a larger scale may result in support of the prediction that forest removal also leads to increased soil temperature. To prevent damage to the island's waterways, we support the Virgin Islands law (Title 12, Chapter 3 section 123) prohibiting cutting of any trees with 25 feet of the edge of a watercourse. Enforcement of this code would simultaneously protect forests, fresh water, soil, and coastal marine systems.

Presentations arising out of this project were presented by UVI students who participated in this project. Both students were junior biology majors and they made presentations at the UVI Annual Fall Research Symposium held on the UVI St. Thomas campus on Sunday, September 21, 2009. The names of the students and the titles of their presentations were as follows:

- Balkaran, Hemma, "A Comparison of Soil Characteristics Based on Land-cover Classification in St. Croix, U. S. Virgin Islands"

- Muhammad, Tristian, "A GIS Analysis of St. Croix's Waterways"

In summary:

1. The GIS training for this project effectively prepared UVI students to execute a research project using ArcGIS 9.1 and additional tools
2. The method of using GIS technology and an existing land-cover change map for St. Croix was an effective in selecting sample sites and the USDA Soil Quality Test Kit was an effective way of collecting data from ephemeral streams during the dry season.
3. Results indicate that forested sites tend to be located on steeper slopes, yet have less erosion and significantly greater water infiltration rates than sites experiencing land-cover change.
4. Deforested sites have higher pH values due to exposure of alkaline parent material and recently reforested sites (abandoned agriculture) had potentially harmful levels of salts in the soil.

5. The other variables, while not statistically significant, also showed a trend of forested sites having relatively healthier soil characteristics, and thus supported our original predictions.
6. This method demonstrates potential for a broader application and an analysis of the territory's waterways on a watershed-by-watershed basis.

Table 1. Averages for each measurement by land-cover type.
(Statistical differences between averages are denoted by different letters.)

Measurement	Average values by Land cover change type		
	Stable Forest (FF)	Reforestation (FN)	Deforestation (NF)
Bank slope *	27.0% a	21.0% a	10.9% b
Hill slope*	4.0% a	1.0% b	2.0% ab
Infiltration rate (cm/hr)***	597.4 a	462.0 b	271.0 bc
Relative temperature (^{0}F)	-10.25	-9.36	-8.32
Soil moisture (g/g)	0.160	0.189	0.167
Bulk density (g/cm^3)	1.181	1.061	2.486
Electro-conductivity (dS m^{-1}) *	0.375 a	1.219 ab	2.486 b
pH *	7.49 a	8.21 b	7.66 a

Analysis of variance using Least Squared Means with alpha level of *0.1 or ***.001

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:	2009VI148B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	
Research Category:	Engineering
Focus Category:	Water Supply, Treatment, Water Quality
Descriptors:	
Principal Investigators:	Sangchul Hwang

Publications

1. There are currently no publications from this project. However, at least one will result from this research.
2. A presentation was made at a conference though no proceedings have been published. Information on the presentation is as follows: Hwang, Sangchul, 2009, Small Filtration and Disinfection Unit for Point-of-Entry Cistern Water Purification, 18th Annual Caribbean Water and Wastewater Association Conference and Exhibition, CWWA, St. Thomas, U. S. Virgin Islands.

PROBLEM AND RESEARCH OBJECTIVES

The technology to be used for the provision of water services to communities and areas in specific characteristics is always challenging. When water purification technology similar to what is used in large urban areas is chosen, it will lead to high investments, which cannot be afforded by the majority of small remote communities. It is important to choose technologies that can easily be operated and maintained by local service providers or by community people.

This research aims to develop and evaluate a Point of Entry (POE) Cistern water Purification Unit (CPU) which can be implemented in communities of the USVIs. To meet this end, low-cost, simple, POE sand filtration and disinfection unit was tested in a lab-scale. POE CPU to be developed in this proposed study will benefit many communities which rely on rainwater as their drinking water source (e.g., USVIs). The 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. In other aspects, the results of the proposed study not only strengthen the PI's research thrust on small drinking water system evaluation and development, but also significantly contribute to capacity building for USVIs through seminars and technology transfers in the future.

The proposed research was proposed with a budget of $19,750 during the period of April 1, 2009 to Feb 28, 2010. It encompassed lab-scale research, student training, results dissemination, and a seminar.

METHODOLOGY

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 was collected periodically and stored in a refrigerator at $4^{o}C$ prior to use. It was analyzed for key water quality parameters.

A lab-scale filtration and disinfection unit was constructed. For the sand filtration column, three different sizes of sand were used. 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.

Samples were collected for analyses of physiochemical and biological characteristics of water. For physiochemical water quality parameters, measured were total residual chlorine concentrations, pH, specific conductivity, particle counts and turbidity. Total residual chlorine (TRC) concentrations were monitored with the HACH calorimetric method. The value of pH was monitored with an Oakton pH Meter 300 series. Specific conductivity was analyzed with an Orion Specific Conductivity Meter Model 162. Turbidity was measured with a LaMotte 2020 Turbidimeter. Particle counts were measured with a particle counter (9703 Liquid Particle Counting System, Pacific Scientific, Co.).

For biological water quality parameters, measured were total coliforms (TC), fecal coliforms (FC) and Total Heterotrophic Bacteria (THB) via a membrane filtration technique. Microbial analysis was done within 24 hours of sampling. TC was quantified with m ENDO Broth. All colonies that are red and have the characteristic metallic sheen are counted as TC after incubation for 24 hrs at 35±0.5 ^{o}C. For the FC, m FC broth was used. Tryptic soy broth was used for THB analysis. After incubation for 24 hours at 44.5±0.2 ^{o}C, all colonies developed in blue were counted for the FC. THB analysis was done with a72-hour incubation at 35°C.

PRINCIPAL ACCOMPLISHMENTS AND SIGNIFICANCE

1. *Physiochemical Water Quality- Conductivity*

Conductivity in the final disinfected effluent was increased by ~2 times, but the value was still low enough at ~53 μS/cm. Reduction in turbidity was observed despite the initial increase during the first trial. Residual chlorine concentration was achieved in the range of 0.2~0.7 mg/L which was similar to the targeted concentration (0.5~1.0 mg/L).

2. *Biological Water Quality*

Fecal Coliform (FC) were detected at a concentration of 10 CFU/100 mL in the rainwater collected for the 1st trial (i.e., after 10 mins). However, no FC was found in the rainwater collected and used for the 2nd trial (i.e., after 1 hr). Differences in FC trend were due probably to the dissimilar properties of the influent rainwater with respect to FC concentrations. Unusually high FCs were detected from the gravel filter-backwashed water. However, no FC was found in the sand filter backwashed water.

Total Heterotrophic Bacteria (THB) was also analyzed for both 1st and 2nd trials. However, the colony-forming unit was too many to count for all the samples taken and analyzed, even with 100-time dilution of the samples. Additional run focusing on bacterial water quality is warranted to conduct.

3. CT Values on Microorganisms Removal

Results from the disinfection of the influent water indicated that when the influent was disinfected with a chlorine concentration at 6 mg/L , smaller than 1-log removal was achieved for both total coliforms and THB despite 60-min contact time. Also, very low concentrations (<0.2 mg/L) of free chlorine was quantified after 20-min contact time.

However, when the effluent of the sand filter was disinfected with the same initial concentration of chlorine, 1-log removal and 1.5-log removal of both microorganisms was achieved with a contact time of 30 mins and 60 mins, respectively. Residual free chlorine concentration was maintained at 3 mg/L. It should be noted that the sand filtration reduced the concentrations of total coliforms from 823 to 400 CFU/100 mL and THB from 42×10^3 to 7.4×10^3 CFU/100 mL.

Alternative Water Treatment Technologies for An Aquaponic System.

Basic Information

Title:	Alternative Water Treatment Technologies for An Aquaponic System.
Project Number:	2009VI150B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	U.S. Virgin Islands
Research Category:	Water Quality
Focus Category:	Conservation, Agriculture, None
Descriptors:	None
Principal Investigators:	Jason James Danaher

Publication

1. Publications are forthcoming.

PROBLEM AND RESEARCH OBJECTIVES

Aquaponics is the combined culture of fish and plants in a recirculating, aquaculture system and has received considerable attention as a result of the system's capability to raise fish at high density, control water parameters, minimize water exchange, and produce a profitable vegetable crop. Although the vegetable crop is responsible for the direct assimilation and relocation of dissolved fish wastes and products of microbial breakdown, recirculating aquaponic systems still require methods to remove total suspended solids (TSS). The TSS are small particulate matter from uneaten feed, fish feces and biological growth that would cause sub-optimal water quality characteristics if not removed from the aquaponic production system. Primary effluent treatment devices are critical for sustaining aquaponic systems because quick and efficient TSS removal maintains optimal water quality parameters for fish and vegetable production.

Currently, the University of the Virgin Islands (UVI) recirculating aquaponic system uses a cylindro-conical clarifier for TSS settlement and discharge; however, a parabolic screen filter could replace the current clarifier in the aquaponic system resulting in improvement of TSS removal rates and reduction in initial capital expenses. There currently are no published research articles on the use of parabolic screen filters for water treatment in aquaponic systems. The objectives of this experiment were to compare water quality parameters, Nile tilapia (*Oreochromis niloticus*) production, and water spinach (*Ipomoea aquatica*) production between raft aquaponic systems using either a cylindro-conical clarifier (Control) or parabolic screen filter (PSF).

METHODOLOGY

Experimental System

The experiment was carried out in six, outdoor aquaponic systems located at the Agricultural Experiment Station, University of the Virgin Islands, Kingshill, United States Virgin Islands, USA. The experiment consisted of two treatments with three replicates each. The Control used the traditional cylindro-conical clarifier for primary treatment of solids and treatment one used the Parabolic Screen Filter (PSF) for primary treatment of solids. The clarifier had a water volume of 1.7-m^3 with a baffled wall perpendicular to the waste stream flow to slow water velocity and prompt solids settlement. The PSF had a volume of 0.13-m^3 and a 200-micron, wedged-wire removable screen with a total filtration area of 1,440 cm^2.

Each experimental system was constructed under a cold frame but only the fish culture tank was shaded with a 100% high density polyethylene shade cloth to prevent sun exposure and algal growth. Each experimental system consisted of a fish culture tank (7.8 m^3), the primary filtration method tested, a net tank (0.7 m^3) with orchard netting, two hydroponic raceways (area 6.1×1.2×0.3 m each; total volume 4.4 m^3), a sump (0.6 m^3), and a 1/6 Hp centrifugal pump to return water to the fish culture tank. Water flows from the fish tank through the other system components by gravity and returns to the sump, which is the lowest point in the system. The pump returns the water to the fish tank from the sump and the pump's flow rate was maintained at 57 L/minute. Hydroponic raceways were lined with a 20-mil white liner. All experimental units were aerated by one, 1.5 Hp regenerative blower. Each system's fish tank had twelve, 8.0×4.0 cm silica air stones spaced 0.75 m apart around the tank perimeter and each hydroponic trough had four, 8.0×2.5 cm silica air stones placed in the middle of each trough and spaced ever 1.2 meters.

Water Quality

Dissolved oxygen (DO), temperature, alkalinity, and electrical conductivity (EC) were monitored biweekly directly from each aquaponic system. The pH was monitored three times per week to maintain a desired pH of 7.0. The addition of 300 – 500 grams of calcium-hydroxide [$Ca(OH)_2$] or potassium-hydroxide (KOH) were added on an alternate basis when pH fell below 7.0. Iron chelate (13% EDTA Fe) was added at a rate of 2 mg/L initially and thereafter periodically to prevent nutrient deficiency. One, 250-mL grab sample was taken biweekly from the end of the second hydroponic raceway and a HACH DR/2000 spectrophotometer was used to measure total ammonia-nitrogen (TAN), nitrite-nitrogen (NO_2-N), and nitrate-nitrogen (NO_3-N). One, 250-mL grab sample was taken biweekly from the end of the second hydroponic raceway and sent for lab analysis for macronutrient and micronutrient levels in the aquaponic system.

Total-suspended solids (TSS) concentration entering and exiting each filter along with TSS concentration exiting the net tank were sampled biweekly one-hour after the morning feeding. A 2.5-cm PVC sampling port was installed just before and after each filter for sampling purposes. At each sampling event a 4-L bucket was filled to flush settled solids from the sampling port. Then a second 4-L sample was taken from which one, 250-mL aliquot was collected to analyze TSS concentration.

Wastes were discharged twice daily from each filter (0900 and 1600 h). The volume of effluent discharged from each filter was quantified at least twice weekly. Additionally, the TSS concentration of discharged effluent from each treatment was measured biweekly from one, 250-mL aliquot. Also one, 250-mL grab sample was taken, monthly, from the discharged effluent and sent for lab analysis for macronutrient and micronutrient levels. At the end of the experiment the orchard netting in each experimental unit's net tank was cleaned of solids via gentle shaking. The slurry in the net tank was manually stirred to suspend solids and two, 250-mL aliquots were taken to measure TSS concentration.

Tilapia

On 4 November 2009, sex-reversed male Nile tilapia (*Oreochromis niloticus*) were counted and weighed into groups of 40 fish and stocked in rotation until each experimental unit was stocked with 360 fish (47 fish/m^3). The initial average weight of individual fish was 231.8 g. Tilapia were fed an extruded diet containing 32% protein (PMI Nutrition International, Mulberry, FL, USA) twice daily (0900 and 1600 h) based on the recommended feeding rate of 60 – 100 grams/diet/m^2 of hydroponic plant growing area (Rakocy 1997). The culture period for tilapia was 79 days and tilapia were harvested on 22 January 2010. A final count was conducted to determine survival and bulk weight was recorded for each tank to determine final average weight, production, and calculate feed conversion ratio (FCR).

Water Spinach

Cuttings of water spinach (*Ipomoea aquatica*) were allowed to root over a two-week period in a commercial-scale aquaponic system. On 31 October 2009 each experimental system had a total weight wet of 3.3 ± 0.1 kg spinach transplanted into the hydroponic raceways. Spinach was placed on-top polystyrene floating boards, but the roots were able to contact the water through a series of 4.8-cm diameter circular cutouts. Spinach was harvested every three weeks by cutting and removing the leaves and stems and allowing the plant to grow back. Spinach was sprayed twice weekly with DiPel® PRO DF biological insecticide to control caterpillar pests. The spinach was grown for 81 days and on 20 January 2010 all spinach was removed from each experimental unit and total wet weight of spinach production was calculated. Total spinach production did not include roots, only the leaf and stem biomass harvested from the top of the polystyrene sheets. On 20 January cuttings of the spinach were taken from each treatment to determine the % moisture content and samples of leaf and stem were sent for plant tissue analysis.

Water quality, tilapia production and spinach production data from each treatment were evaluated for significant differences in Microsoft© Excel 2007 using t-test analysis. All percentage data was transformed to arc sin values prior to analysis (Bhujel 2008); however, data are presented in the untransformed form to facilitate interpretation.

PRINCIPAL FINDINGS AND SIGNIFICANCE

In conclusion, the Parabolic Screen Filter (PSF) used in this experiment did not adversely affect fish production, water spinach production, or water quality parameters compared to the Control. However, it was not as effective as a primary treatment device for TSS in the aquaponic system when compared to the Control. If the PSF evaluated is to be installed into a similar scale aquaponic system the authors recommend the removable, wedge-wire screen be cleaned in six hour intervals. Alternatively, installing a PSF with an increased screen surface area (> 1,440 cm^2) may result in less frequent clogging by distributing solids in the waste stream over a larger surface area. Although the PSF used in this study was designed to handle a flow rate of 265 L/min the authors do no recommend it be used in a commercial scale aquaponic system. In the present study the PSF frequently clogged with a maximum daily feeding rate of 1,120 grams of fish diet and a flow rate of 56 L/min. In a commercial scale aquaponic system the PSF would have to handle a daily feeding rate exceeding 8,500 grams of fish diet and a flow rate of 190 L/min. We speculate this increased loading rate would create frequent clogging and become problematic for system management. There are larger PSF units available and these larger units should be tested in a commercial scale system to determine their efficacy. Based on this study a PSF would result in increased daily management of the raft aquaponic system to discharge solids compared to a system utilizing a cylindro-conical clarifier. Additionally, if solids bypass the PSF than increased cleaning of the net tanks will also be required. However, if improved profits are recognized through increased space for hydroponic growing bed area in confined spaces (i.e. temperate climate greenhouses) then a compact PSF may be justified in a raft aquaponic system despite the requirement for increased waste management by employees.

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:	2/28/2010
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. This project is not yet completed.

PROBLEM AND RESEARCH OBJECTIVES

Coral reefs and other vulnerable nearshore marine resources of the 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, erodible 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 Virgin Islands 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, and physical disturbance can cause coral morbidity and mortality. An improved 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.

The objectives of this research are: (1) to quantify sediment export from St Thomas watersheds, and (2) to begin to provide a predictive capability to allow better management of watersheds to reduce erosion and sediment export. Considerable research has already been conducted on St John, but that island is very different from St Thomas in two critical ways. First, St John has no perennial streams, unlike St Thomas which has two. Second, St John has a much greater number of unpaved roads, which act as the major sediment source there. The present research takes advantage of a continuously flowing stream, and seeks to better understand the influence of the kinds of development that occur on St Thomas.

Some of the questions being answered by the current research are:

- How does fine sediment export during small rain events compare to that in larger storms?
- How does fine sediment export change over the course of individual storms? For example, is there a “first flush” effect?
- What is the relationship between sediment flux drivers (rainfall amount, rainfall duration, time since antecedent rain event, and season) and the outcome, fine sediment export?
- Does the exponential increase in sediment flux with discharge that has been observed in some other systems apply on St Thomas?
- Do coastal ponds capture a significant portion of eroded sediment delivered to them from upstream watersheds?
- Over the last century, do coastal ponds reveal changes in sediment accumulation rates, which may be linked to historical changes in land use?
- Does sediment accumulation in coastal ponds match predictions based on STJ-EROS, thereby further validating this model?
- How do rainfall amounts compare over the 3 km distance between Cyril King airport and our monitoring sites in the Dorothea gut watershed?

METHODOLOGY

Stream Monitoring

We have deployed a YSI 6920 Multi-Parameter Water Quality sonde in Dorothea Gut at the location of the former USGS gauging station. The sonde is equipped with probes to measure pressure (stage/water depth), turbidity (a surrogate for suspended sediment), temperature, dissolved oxygen (DO), and pH. The sonde is collecting data at a 15 minute interval unattended for one month periods. The two optical probes (turbidity and DO) are equipped with mechanical wipers that clear the surface of any biofouling immediately before measurement. The sonde is rugged and is designed to withstand submergence to depths up to 50 m. A v-notch was added by us to the weir in June 2009. This improvement allows us to monitor low changes in flow with greater accuracy.

The selected site has a number of advantages:

(1) Considerable past discharge data exist, allowing us to place the results of our one year project in a much longer (decadal) context.
(2) A broad crested weir was established by the USGS. We have added a v-notch to this weir to allow reliable measurement of lower flows.
(3) The watershed has an intermediate level of development and includes residential, agricultural, and commercial land uses, and is typical of large portions of St Thomas.

In conjunction with the stream monitoring, we have deployed two Rainwise RainLogger digital rain gauge/data logger systems. These devices measure precipitation with 0.25 mm (rainfall amount) and 1 minute (temporal) resolution. The gauges are necessary because of the observed differences with the record of the nearest existing rain measurement station, at Cyril King Airport. One gauge is situated at the weir, while the other is placed 0.8 km away to reflect the center of the upstream watershed.

Data from the sonde and rain gauges are being downloaded monthly, and the devices checked after major storms. The sonde is also recalibrated monthly and receives fresh batteries. Researchers visit the monitoring site throughout the year under a range of discharge conditions to collect samples for suspended particulate matter (SPM) analysis to calibrate a turbidity-SPM correlation.

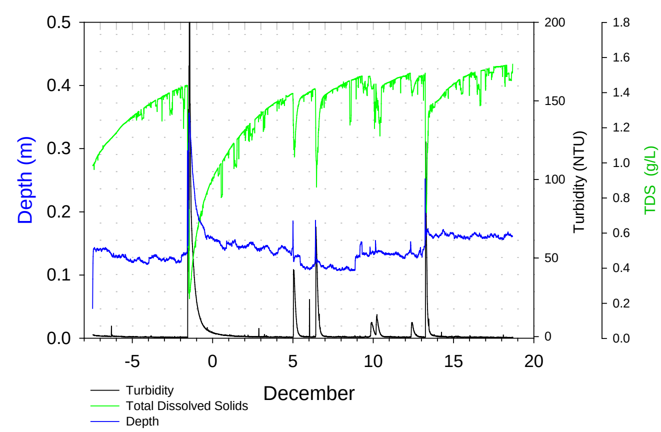
Coastal Pond Sediment Accumulation Rate Analysis

Sediment cores are being collected from ponds along the coast of St Thomas. Geomorphologically, these systems tend to be small embayments whose connection to the sea has been closed by some combination of reef building and longshore drift. Because they lack direct connection to the sea, they act as settling basins and capture a large share of the sediment delivered to them by guts during storms. From aerial photos we identified several ponds, and have already sampled three of them (adjacent to Perseverance Bay, Fortuna Bay, and above Sapphire Bay). We are collecting 2 to 4 cores (depending on pond size) that are 50 to 70 cm long in 5 cm diameter core liners from each pond. Cores are extruded and sectioned at 1 – 2 cm intervals, dried to constant weight, and a subsample (typically 5 g) sealed in plastic tubes for gamma ray analysis on a Canberra well detector-multichannel analyzer system in GB's laboratory at Yale. Samples are counted for ^{210}Pb, ^{137}Cs, ^{226}Ra, and ^{7}Be. ^{210}Pb and ^{226}Ra data can be combined to derive unsupported ^{210}Pb ($^{210}Pb_{xs}$), which declines exponentially with depth in steadily deposited sediments. Sediment accumulation rates can be evaluated by means of either the constant initial concentration or constant rate of supply model. Breaks in slope of log($^{210}Pb_{xs}$) vs depth plots are indicative of changes in sediment accumulation rate. To account for the effects of compaction, depth accumulation rates (cm yr^{-1}) can be converted to ones based on mass (g cm^{-2} yr^{-1}), though we have found little influence of compaction in the cores we have tested from St Thomas so far. ^{137}Cs deposition reached a maximum in 1963 because of atmospheric weapons testing. A sharp peak in sediments serves as a marker for that date, permitting calculation of average sediment accumulation rate for the past 45 years. (However, surface mixing can obscure that signal, as we have found in some of the cores analyzed so far.) ^{7}Be has a short half life (53 d) and in most cases is an indicator of the sediment mixing depth. Taken together, these radionuclide measurements provide detailed information on sediment accumulation over the past 120 years, as well as the extent of mixing processes occurring near the sediment water interface.

PRINCIPAL FINDINGS TO DATE AND SIGNIFICANCE

Stream monitoring

Fig 1: Dorothea - December 2009



We have collected data continuously from late June 2009 through the present, with short breaks during which the YSI sonde was returned to the laboratory to download data and for routine maintenance. Figure 1 shows typical data. The blue line is water depth, corrected for atmospheric pressure and water temperature. A small (~ 1 cm) daily variation is evapotranspiration over the day-night cycle. During larger storms, water depth and turbidity (black line) both increase dramatically, while total dissolved solids (green

Fig. 2: Turbidity - Suspended Matter Correlation

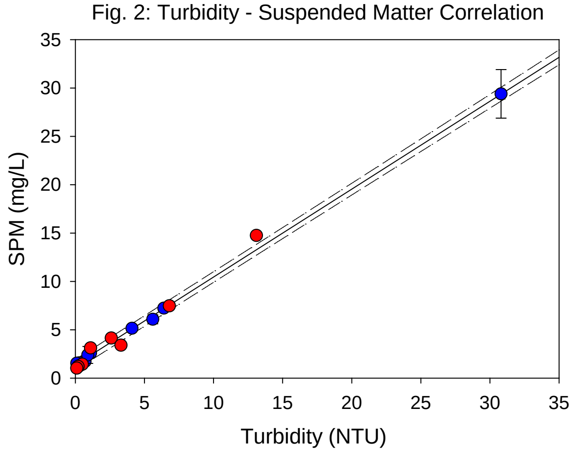
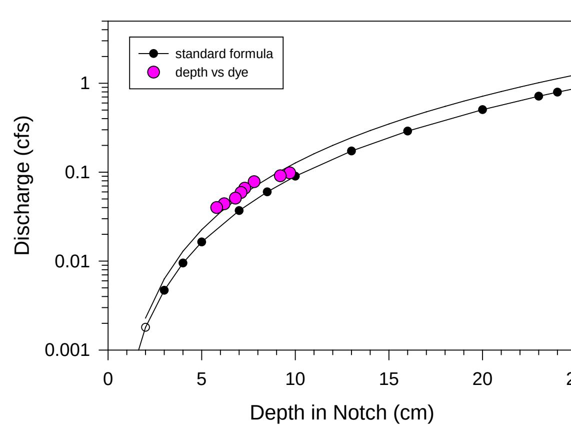


Fig. 3: V notch weir head-discharge



line) decreases proportionately. A good example is 28 November (a date which plots at "-2" on the x axis) when 1.45 cm of rain fell. We have calibrated suspended matter against turbidity (Fig. 2) and discharge against water depth (Fig. 3). This allows us to calculate the total export of eroded sediment in each storm. In the storm on 28 November 2009, we calculate that about 150 kg of sediment was carried out of the watershed by the stream. Measured sediment fluxes like this can be judged against export coefficients measured or estimated in previous studies comparing land use and erosion.

Sediment accumulation in coastal ponds

Sediment accumulation rates (SARs) in the three coastal ponds we have sampled so far show similarities and differences. Within single ponds, multiple cores reveal relatively little intercore variation. Cores in Perseverance Pond are accumulating at a rate of 1 – 2 mm/yr. Fortuna Pond is accumulating sediment at a similar slow rate of about 1 cm/yr. By comparison, the pond above Sapphire Bay is filling in more rapidly (ca. 9 mm/yr, though only one core collected there has yet been measured). These rates and their differences will be evaluated in terms of land use-land cover in their respective watersheds.

Spatial variations in rainfall amounts

Our measurements of rainfall in the Dorothea Gut watershed are correlated with those at Cyril King Airport, approximately 3 km distant. For daily rainfall, $r^2 = 0.66$, whereas for hourly rainfall the r^2 is only 0.24. Both correlations are significant at better than the $P = 0.001$ level. Nevertheless, there are many occurrences where significant rainfall was observed at one site but not the other. We are continuing these comparisons with a second rain gauge in the Dorothea watershed.

NEXT STEPS

We will continue to monitor water quality and hydrology characteristics in Dorothea Gut through a full year and beyond. A major goal is to evaluate sediment export amounts in rain events of various intensities, and to try to establish a quantitative relationship between the two. At the same time we will evaluate other possible controlling variables, like season and the length of antecedent dry period.

We will complete our analysis of cores collected from Sapphire Pond, and sample and analyze at least one additional pond with contrasting land use. Our results for sediment capture within the ponds will be compared to estimates of erosion within their watersheds to evaluate how efficiently the ponds act as sediment traps.

Information Transfer Program Introduction

Information dissemination is an important aspect of the work of the Virgin Islands Water Resources Research Institute. The VI-WRRI joins the University of the Virgin Islands in recognizing that our role in the Virgin Islands community is not only to provide training and conduct research but also to spread information gained through our research and the research and other experiences of others. With the islands of the Virgin Islands being geographically separated from each other, sharing information within the U. S. V. I. takes on special challenges in many ways similar to sharing information with and from our close neighbors in the Caribbean, collaborators on the U. S. mainland and from others around the world whose water issues are similar to those in the USVI. All participants in the VI-WRRI program are strongly urged to not only produce reports but also to hold workshops and seminars to share their findings. They are also encouraged to not just publish their work through scholarly papers but also use the news media, brochures, factsheets and informal meetings. This section of the annual report speaks to projects supported specifically through the information transfer program but dissemination of information is an integral part of all VI-WRRI undertakings.

This year it was a particular pleasing for the VI-WRRI to collaborate with other agencies in the USVI in the holding the Eighteenth Caribbean Water and Wastewater Association's annual conference. A summary report on this conference follows as does the final summary on a project that was part of last year's VI-WRRI's information transfer program.

Virgin Islands Water Resource Map Study

Basic Information

Title:	Virgin Islands Water Resource Map Study
Project Number:	2008VI118B
Start Date:	3/1/2008
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Water Quality
Focus Category:	Management and Planning, Sediments, Surface Water
Descriptors:	
Principal Investigators:	Stevie Henry

Publications

1. There are currently no publications.
2. Presentations were made at conferences and workshops though no proceedings have been published. Information on the presentations are as follows:
3. Henry, Stevie, 2009, Applications in GIS Technology in Water and Wastewater Management, 18th Annual Caribbean Water and Wastewater Association Conference and Exhibition, CWWA, St. Thomas, U. S. Virgin Islands.
4. Henry, Stevie, 2010, A Framework for Sharing and Updating Resource Maps, Tenth Virgin Islands Nonpoint Source Pollution Conference, Department of Planning and Natural Resources Management, St. Thomas, U. S. Virgin Islands.

PROBLEM AND RESEARCH OBJECTIVES

A sediment reduction program was prepared for the U.S. Virgin Islands Department of Conservation and Cultural Affairs in 1979 by the firm BC&E-CH2M Hill. The stated purpose of the program was to minimize the occurrence of soil eroding and being transported into the islands' coastal waters. A sediment reduction map was produced as an output of the study used to establish the Virgin Islands Sediment Reduction Program (VISRP).

The sediment reduction maps were produced to be used for planning and enforcement within the VISRP. The sediment reduction maps were named the "Water Resources Map" and became a requirement for the acquisition of a development permit. The maps display terrestrial and marine features that are directly related to sediment reduction or biological communities sensitive to the affects of sediment discharge.

Despite changes to the landscape and seascape of the Territory, the water resources map has not been updated and development permit applicants are still required to submit a copy of the map section with the area to be developed. There is evidence that the delivery of sediment to the coastal system has increased exponentially during the past 50-60 years. Development practices ignoring the management of soil erosion has been identified as the primary contributor to sedimentation. How reliable is the information contained in the water resources map for making land use decisions?

Impoundments are major features on the *Water Resources Map*. They serve an essential role in sediment control. The overtopping protection and holding capacity are indicators of how well an impoundment is functioning.

This study reviewed the relevancy of how the *Water Resources Map* is used currently. The existing condition of impoundments within study areas on St. Thomas and St. Croix were surveyed. Recommendations were developed for expanding, integrating and maintaining updates of the data needed for planning and enforcing sediment controls.

The goal of this project is to evaluate the reliability of the impoundment data contained in the water resources map for making land use decisions. This will be accomplished by evaluating:

- How the inventory of impoundments is maintained and used by the Department of Agriculture.
- How is the updated Department of Agriculture impoundment inventory shared with and used by other users (Department of Planning and Natural Resources and engineers, etc.)?
- Evaluate how GIS technology could be used to improve planning and enforcement of sediment reduction.

METHODOLOGY

Inventory of impoundment ponds

Since the water resources map was produced 20 plus years ago there have been significant advances in desktop Geographic Information System (GIS). These advances have made the collection, update, analysis and dissemination of spatial data cheaper and more efficient.

The GIS inventory of impoundment ponds for this study is based on a comparison of hardcopy *Water Resource Maps* for St. Thomas (Section 13) and St. Croix (Section 4) to existing digital dataset maps. These digital maps include the U.S. Department of Agriculture Soil (1992), the University of the Virgin Islands, Virgin Islands Vegetation Community (2002) and 2007 imagery and elevation for the study area. The inventory includes ponds that have been eliminated or added since 1978.

Figure 1 Study area for St. Thomas

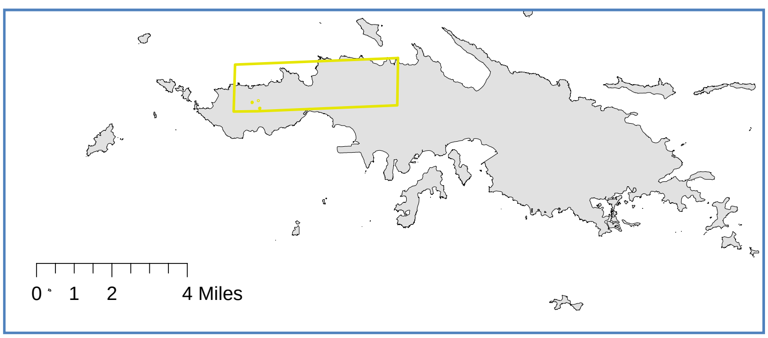


Figure 2 Study area for St. Croix

A 10 item checklist was used to assess the condition of impoundments during field surveys. The score for each item was based on two factors: the level of maintenance needed and the level of harm to be expected if the level of required maintenance is not met. Based on the total score, surveyed impoundment ponds were given one of four classifications:

1	0	= No maintenance needed
2	0.01 ≤ 24.9	= Slight maintenance needed
3	25 ≤ 49.9	= Intermediate maintenance needed
4	50 ≤ 100	= Major maintenance needed

Focus Group

A focus group reviewed the current workflow for maintaining the information provided in the *Water Resource Map*. The focus group participants included planners, natural resource managers, scientists and other fields related to land development. The group gave feedback on recommendations for monitoring sediment/impoundment ponds.

PRINCIPAL ACCOMPLISHMENTS

Data Collection

To obtain an inventory of the impoundments in the study area, the Department of Agriculture and the Department of Planning Natural Resources were approached. As part of its function the Department of Agriculture assist farmers with the construction and the maintenance of impoundments as a water source. In conjunction, the Department of Planning and Natural Resources reviews, issues development permits and monitors the construction and maintenance of impoundments.

There is no compilation of how much, or what was dredged, when or where by Department of Agriculture. The most comprehensive impoundment inventory found was a map and table of surface water impoundments on St. Croix published in the *Water Plan for St. Croix, U.S. Virgin Islands* (1976). The inventory table feature for each impoundment: Code Number (USDA assigned), Capacity, Year Built, Year Renovated and Owner. A similar inventory does not appear to exist for St. Thomas.

GIS point layers containing the inventory of ponds for the St. Croix and St. Thomas study areas were created for this project. The LAT-LONs were generated from the centriod of ponds delineated in the 1992 USDA Soil Survey and the 2000 Virgin Islands Vegetation Community dataset. Ponds shown on the hardcopy map or aerial imagery were digitized on screen. The St. Thomas point layer has a total of 31 features and the St. Croix 43 features. A total of 80 pictures have been catalogued: 24 for St. Thomas and 56 for St. Croix.

A University of the Virgin Islands undergraduate, biology major was hired and trained to complete the GIS layer for St. Thomas. After conducting a literature review of best practices for monitoring sediment/impoundment ponds the student developed a 10 item check list. The student developed a program macro which allows a user to enter a value for each of the 10 items on the check list then present a maintenance required score with pictures (see example of output in Figure 3).

Through a focus group meeting discussion, the coordinator for the St. Croix Education Complex High School, Math and Environmental Science Summer Academy (MESA) and the engineer for the Department of Agriculture agreed to collaborate on having students conduct water and soil test at two impoundments within the study area. The MESA students Non-Point Source Project conducted soil and impoundments in the study area (see Appendix A.). Inspired by their summer experience the teacher and students developed a project to study the impact of water hyacinths on the ponds during the school year.

Figure 3 Screen shot of impoundment maintenance scoring macro

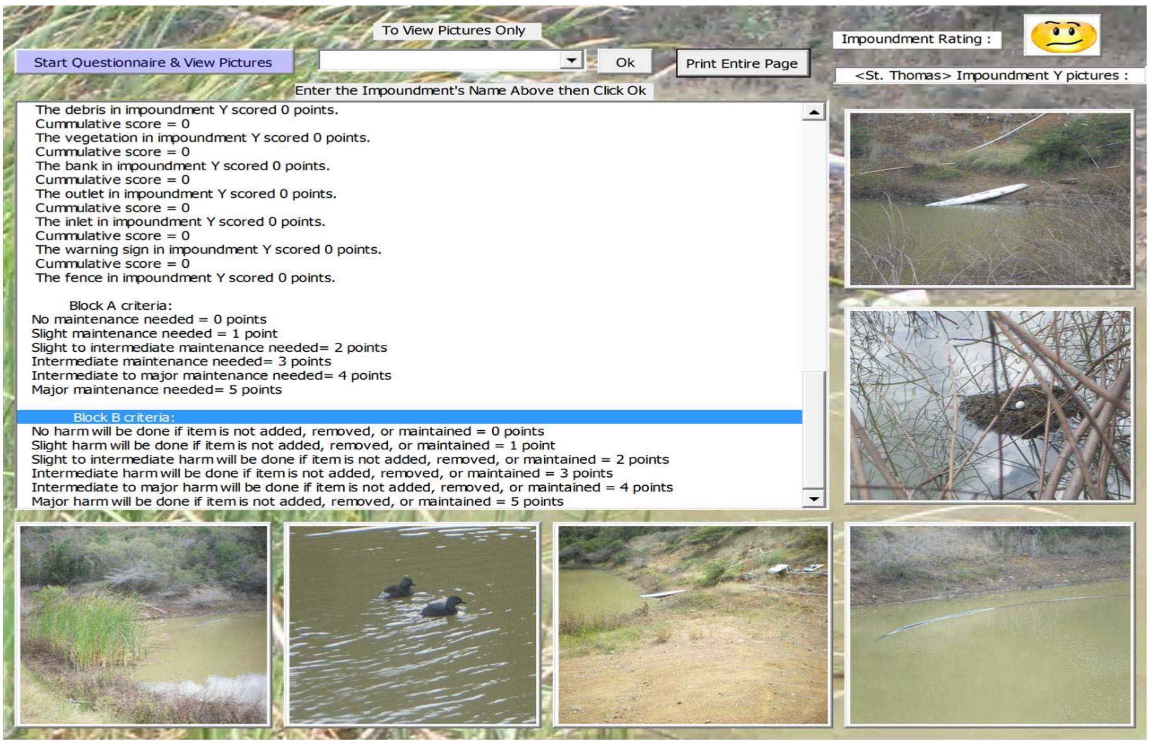
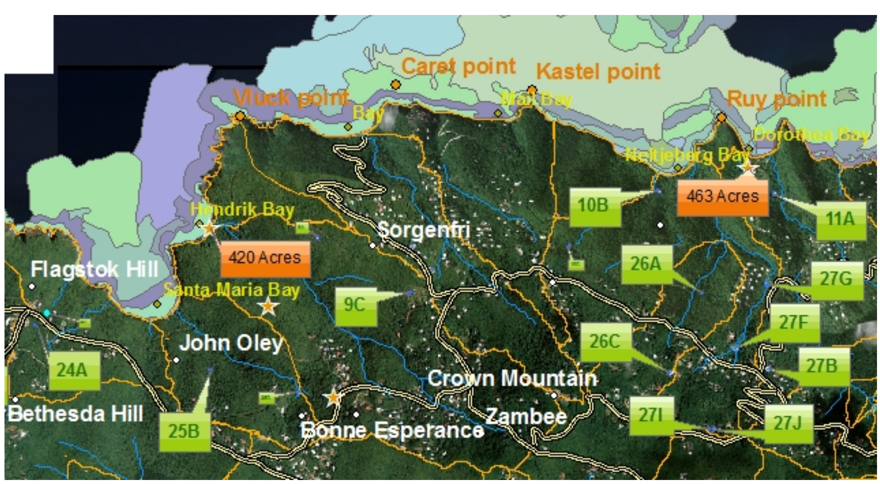


Figure 4 View of the UVI student St. Thomas Water Resources GIS project map view



Map Relevance & Reliability

The value of a resource map is determined by its relevance and reliability. Relevance refers to a resource map providing the information needed by a user. Reliability refers to the data creator or provider assuring the quality of data provided. Table 1 shows that impoundments have been eliminated and constructed since the publication of the official *Water Resource Map* but 100% of these changes are not shown; therefore, the official maps are currently irrelevant however, as Figure 5 shows they are historically relevant.

Table 1 Inventory of Impoundments Existing in Study Area

	Original Inventory of Impoundments	**Impoundments Eliminated**	**Pre-1978 Impoundments Existing**	**Ponds Mapped Post-1978**	**Ponds Existing in 2009**
St. Thomas	27	8	19	5	24
St. Croix	23	3	20	20	40

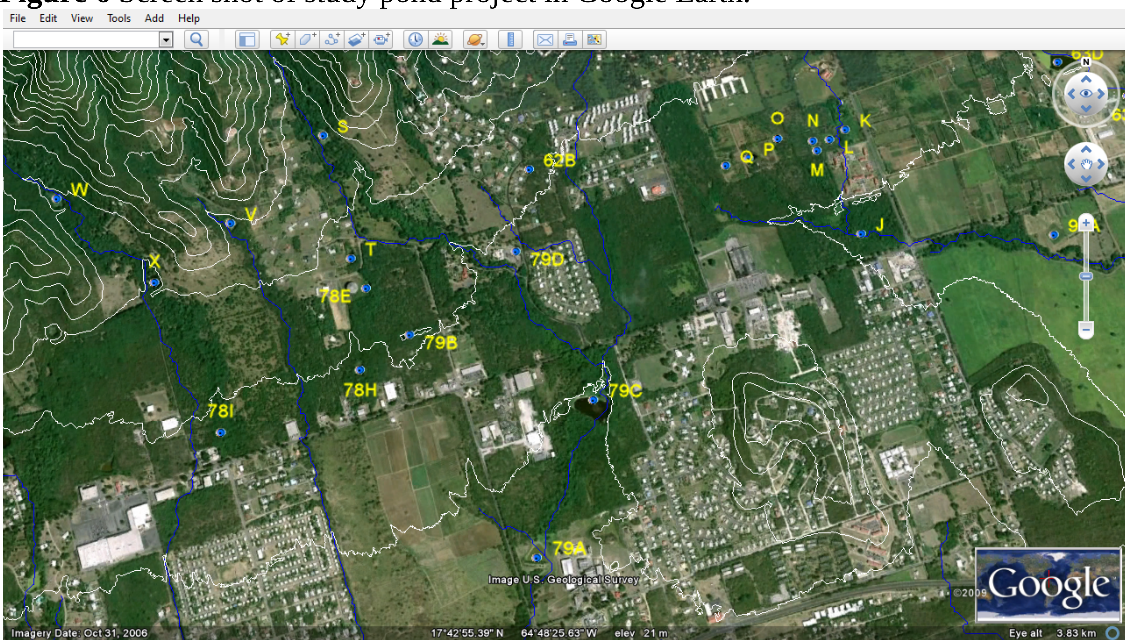
Figure 5 Shows the USDA Soil 1992 dataset delineation of ponds in Upper Love, St. Croix which have been eliminated by residential development

Resource Maps

There are multiple sources of GIS layer for the U.S. Virgin Islands containing impoundment ponds as a map feature. One such source is the USGS National Hydrography Dataset (NHD). This dataset provides the most comprehensive inventory of the islands drainage networks. The data contained in the attribute table for this dataset is a compilation of data sources - federal agencies (e.g. EPA and the U.S. Army Corp of Engineer) as well as local programs. The U.S. Fish and Wildlife Service, National Wetland Inventory is another national dataset that includes mapping of surface water bodies in the U.S. Virgin Islands. Due to the lack of local stewardship, the information in the dataset is limited to the geometric values and the agency's classification of the feature. The other fields such as name are given a NULL value.

The ArcMap® GIS project with the inventory of the study ponds along with other features such as elevation contours and ghuts was converted to a KMZ file format to illustrate how using Google Earth® the data could be shared with decision makers as well as the general public.

Figure 6 Screen shot of study pond project in Google Earth.



RECOMMENDATIONS

The participants in the focus group meetings were presented recommendations for utilizing GIS to support the update of development monitoring and management tools such as the *Water Resource Map*. Based on consensus the recommendations are:

1. To improve resource management integrate data required to meet local or federal reporting mandates with existing national datasets;
2. Create report that measures growth and change.
3. Establish regular period for data reporting as part of the data collection planning process. This process includes that the department with jurisdiction has the fiscal and human resources to not only develop but also update and maintain reports and reporting tools.
4. Store reports in portable formats enabling maximum access and are user-friendly for local resource managers and the general public.
5. Design maps that translate reports thus promoting investigation of relationships across topics and enhancing the ability of users to visualize action steps to be taken.

CONCLUSION

The finding of this study reveals that the inventory of impoundment ponds for the study areas has changed significantly. The update of aerial imagery and GIS layers makes mapping the location of the ponds easy. The area of challenge is assessing and monitoring impacts of development on these features. The solution to overcoming this challenge requires the development and implementation of a data collection strategy which involves a multi-agency approach. For instance, during a focus group discussion a representative from the local office of disaster preparedness suggested working with the Department of Agriculture in making maintenance of the impoundments part of the Territory's flood mitigation plan in order to secure some funding.

The performance of the students connected with this project demonstrated the opportunity to use local capacity to address this challenge. Moreover, the activity enhanced the students learning experience by allowing them to apply their knowledge to the real world.

The Eighteenth Annual Caribbean Water and Wastewater Conference and Exhibition

Basic Information

Title:	The Eighteenth Annual Caribbean Water and Wastewater Conference and Exhibition
Project Number:	2009VI165B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	NA
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, Law, Institutions, and Policy
Descriptors:	
Principal Investigators:	Henry H. Smith

Publication

1. Presentations made at this conference are available on compact disks by contacting the Caribbean Water and Wastewater Association at its website at www.cwwa.net/home/

PROBLEM AND INFORMATION TRANSFER OBJECTIVES

Water resources issues in the Caribbean islands tend to be the same from island to island. In general the islands are relatively small, their geologies are similar, annual rainfall amounts are approximately the same and seasonal variations are consistent. The islands are all transitioning and there are increasing demands for high quality water. The flow of water resources information between the islands though is not as plentiful as desired. One reason for this might be the political boundaries between Caribbean countries and the resulting difficulties of travel between islands, restrictions due to funding limitations and requirements and language and other communication obstacles.

The Caribbean Water and Wastewater Association is a non-governmental organization registered in Trinidad and Tobago. Its mission statement provides for the advancement of the science and practice of water supply, wastewater disposal and solid waste management, and promotes the efficient management of utilities for the sustainable development of Caribbean people by:

- Facilitating research and development and the use of appropriate technologies;
- Identifying emerging needs and providing value-adding opportunities for our members;
- Promoting the professional development of our members by providing access to accredited education and certified training opportunities;
- Facilitating the sharing of members knowledge and experiences by providing an efficient support network;
- Building alliances and partnerships to strengthen the development of our members and member institutions;
- Advocating on critical issues affecting the water, wastewater and solid waste industries and our membership.

The Virgin Islands Waste Management Authority (VIWMA) is an autonomous agency in the U. S. Virgin Islands that was created to develop and implement a comprehensive waste management program that would provide financial accountability, fiscal management and operational efficiency of waste management programs in the Virgin Islands. This would ensure the continued protection of public health and the environment.

These two agencies along with the Virgin Islands Water and Power Authority and the Virgin Islands Department of Tourism and others collaborated with the Virgin Islands Water Resources Research Institute (VI-WRRI) at the University of the Virgin Islands to host the Eighteenth Annual Caribbean Water and Wastewater Conference and Exhibition. The VI-WRRI has convened several similar conferences in the past. The most recent of these were the Seventh Caribbean Islands Water Resources Congress which was held in St. Croix, USVI October 25 – 26, 2007 and Let’s Talk Water! Water Voices From Around the World which was held in St. Thomas on February 6, 2009.

The 18th Caribbean Water and Wastewater Association Conference and Exhibition was expected to explore themes of relevance to the water and wastewater sector and was organized around a conference agenda to include

(i) a high level session providing for presentation by government officials and the leadership of the local utility companies,

(ii) technical presentations by practitioners, researchers and commercial interests, workshops for skill development and training and

(iii) exhibitions by suppliers, consultants and affiliate organizations.

It was planned that about 300 persons would participate in the meeting. These persons were to consist principally of water and wastewater professionals and laymen from the Virgin Islands, and neighboring Caribbean Islands. Historically there has also always been significant participation in this conference and exhibit by persons from outside the region.

Conference objectives were to include

- Facilitation of the exchange of ideas between water professionals on topics of regional concern
- Sharing of information and experience that will allow conference participants to understand and offer ideas on the water, waste and sanitation issues in the U. S. Virgin Islands
- Exploration of themes relevant to the water and wastewater sector in the Caribbean region
- Exhibition of commercial products and services relevant to water and wastewater professionals in the region
- Showcasing the culture and diversity of the Caribbean Islands.

PRINCIPAL OUTCOMES

Planning for the conference was led by a committee that included representatives of the Water Resources Research Institute at the University of the Virgin Islands, the Department of Tourism, the Waste Management Authority, the Water and Power Authority and others. The committee worked very closely with the Caribbean Water and Wastewater Association. The lead committee was also responsible for establishing and coordinating the work of subcommittees with responsibilities for developing the conference program, arranging transportation and accommodations, and so on.

Announcements were circulated locally, regionally and elsewhere in order to allow for maximum participation in the conference. The internet as well as the traditional media including journals, newspapers, radio and television were used in publicizing the conference.

The conference took place on St. Thomas, U. S. Virgin Islands from October 4 to 10, 2009 at the Marriott Frenchman's Reef and Morning Star Resort. The theme of the conference was "A Green Future – Developing Caribbean Water and Waste Resources." It featured over 50 formal presentations and three technical tours of local water and waste water facilities. 23 countries were represented at the conference, 23 advertisers placed ads in the program book, there were about 50 exhibitors and over 235 individual participants from the Caribbean, the United States mainland, Canada and Europe. Participants included water professionals and policy makers and curious members of the public.

Issues discussed included water conservation and water use efficiency, regulation of the water industry, water recycling and harvesting, water shortages, safe drinking water supplies and energy efficiency in the water industry. Papers presented at the conference were made available to participants on compact discs.

At the closing session of the conference awards were presented to three persons for the work they had done in advancing water resources issues in the Caribbean. The Director of the Virgin Islands Water Resources Research Institute, Dr. Henry H. Smith, was recognized by the Caribbean Water and Wastewater association with as Gold Award Honoree for distinguished and prolonged service and also for special achievement. He was recognized for his more than 25 years of meritorious service in water supply in the Caribbean and for special achievement in the technical field of water supply management in the Caribbean.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	8	0	0	0	8
Masters	9	0	0	0	9
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	17	0	0	0	17

Notable Awards and Achievements

The Director of the Virgin Islands Water Resources Research Institute, Dr. Henry H. Smith, was recognized with a Gold Medal Award by the Caribbean Water and Wastewater Association at its 18th Caribbean Water and Wastewater Association Conference and Exhibition held in St. Thomas, Virgin Islands October 4 to 10, 2009. Dr. Smith was recognized for his leadership in facilitating water resources research, training and information in the U. S. Virgin Islands through the VI-WRRI that was supported by the USGS.

Publications from Prior Years