Virgin Islands Water Resources Research Institute

Annual Technical Report

FY 1999

Introduction

The United States Virgin Islands consists of four principal islands – Water Island, St. John, St. Thomas and St. Croix. The islands are of volcanic origin and the largest of them, St. Croix, covers an area of less than 85 square miles. The average annual rainfall of 40 inches serves as the principal source of natural potable water for residents in these islands where cisterns are required by law. Seawater desalination plants supply the water distribution networks that are restricted to certain areas in the islands due to the hilly terrain. Dependence on rainfall and the expensive desalinated water makes Virgin Islanders very water conscious. There is then a high interest in knowing where and when rainfall occurs. In addition, due to tourism being the basis of the economy, water quality issues are also of great concern. It is important for residents and visitors to have high quality water for consumption and hygienic purposes. Also with the surrounding waters being a principal place for recreation, pristine coastal waters are critical. The 1999 - 2000 program of the Virgin Islands Water Resources Research Institute (WRRI) reflected the water resources issues of concern in the Virgin Islands. One project examined the effects that storm water runoff from the islands' steep slopes had on the fragile coral reef systems that surround the islands. The other project focused on establishing a weather data compilation station for the USVI at the University of the Virgin Islands. In addition to these two new projects, two new projects were continued from previous years. These projects examined the causes and quantification of erosion that occurs due to various land use practices in the islands and determined the appropriate indicators to use in assessing the quality of water in tropical environments. This annual report describes, in the format prescribed by the U.S.G.S., the research training and information transfer activities of the Virgin Islands Water Resources Research Institute during the period March 1, 1999 to February 29, 2000.

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Erosion and Sedimentation on St. John, U.S. Virgin Islands
Project Number	C-01
Start Date	09/01/1997
End Date	02/29/2000
Research Category	Climate and Hydrologic Processes
Focus Category #1	Sediments
Focus Category #2	Hydrology
Focus Category #3	Models

Focus Category #3	Models
Lead Institution	Virgin Islands Water Resources Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Henry H. Smith	Associate Professor	Virgin Islands Water Resources Research Institute	01
Lee MacDonald	Associate Professor	Colorado State University	02
Carlos E. Ramos-Scharron	Student	Colorado State University	03

Problem and Research Objectives

1. Introduction St. John, located approximately 80 km east of Puerto Rico, is the third largest of the island group that comprises the Territory of the United States Virgin Islands. This 50 km2 island is well known for its pristine beaches and the richness of its marine environment. The Virgin Islands National Park comprises about 54% of the total land area and 23 km2 of its offshore waters. The National Park Service, local authorities and residents are increasingly concerned with the potential environmental impacts due to the rapid development on privately owned lands. Even though previous research efforts provided some information on runoff and erosion processes on St. John, a more intense and longer-term field study was needed to better quantify and understand the key processes and sediment sources. The current study responds to this need, and the main objectives were to: (1) measure runoff, sediment production, and sediment delivery rates from undisturbed areas; (2) measure sediment production and sediment delivery from unpaved road surfaces, fillslopes, and cutslopes; (3) construct empirical models to predict sediment production and delivery from undisturbed areas, unpaved road surfaces, fillslopes, and cutslopes; (4) quantify runoff rates and sediment transport through the fluvial system at various scales, and evaluate the role of land use on the observed sediment concentrations; (5) develop a GIS-based empirical sediment routing model for St. John, and evaluate its performance against other commonly-used models; and (6) educate the public about erosion processes, and provide specific strategies to minimize the potential adverse effects of anthropogenic sediment sources.

Methodology

2. Overall Approach, Site Selection, and Methodology The overall project design is based on the concept of a sediment budget, and the ultimate goal is to develop a GIS-based sediment routing model for several watersheds in the island of St. John. More specifically, we are quantifying sediment production rates from different landscape units as well as sediment transport rates at different scales through the fluvial system. The spatial integration of these production and transport rates in a GIS format will allow us to route the movement of sediment through the landscape. The different types of measurements can be divided into; (1) hydrologic measurements, and (2) sediment production and transport measurements. Hydrological measurements are needed because water is the primary detachment and transport mechanism. Because rainfall is the basic driver of runoff, erosion, and sediment transport, we have been measuring precipitation rates at different locations across St. John. We also have been measuring the runoff response at scales ranging from small plots to entire watersheds. Sediment production measurements include erosion rates at the hillslope plot and road

segment scales. Sediment transport measurements are being used to quantify the transport rate of sediment at the road segment, sub-catchment and watershed scales, and these data will be used to estimate sediment yields at each scale. Hydrologic Measurements Precipitation Even though the small size of the island of St. John would suggest a relatively homogeneous distribution of precipitation, wind and orographic effects produce a precipitation gradient that may induce significant differences in erosion and sediment transport rates across St. John. Given this variability, we installed five recording raingauges and one non-recording gauge to document the short-term variations in rainfall and provide the data to develop and test our runoff and erosion models. Two of these stations are in the wet climatic zone (127-140 cm per year), two in the moderate zone (114-127 cm per year), and one in the moderately dry zone (102-114 cm per year). Natural hillslopes Three plots were previously set up in 1996 to measure the magnitude and frequency of runoff from undisturbed hillslopes. Two of these plots are on the western slopes facing Haulover Bay on the drier eastern portion of the island, and the third plot is in the lower Fish Bay catchment. The plots are located on planar hillslopes with gradients ranging from 23-31%. Due to the fact that no recording raingauge was installed in the proximity of Haulover Bay, runoff volumes is related to daily rainfall from East End or recording rainfall data from established stations. Road-segment scale runoff Runoff rates at the road segment scale were being continuously measured at two sites using 8-inch cutthroat flumes, pressure transducers, and data loggers that record the water level in the flume at 5 to 15 minute intervals. The water levels were converted to discharge by standard equations. These data allowed us to quantify the runoff response of the road segments. We were particularly interested in using this data to determine the amount and intensity of precipitation needed to generate runoff from each road segment, the sediment transport capacity of the road surface runoff, and the time distribution of runoff as compared to the precipitation intensity during individual storm events. Suspended sediment data were also being collected at these sites. Watershed-scale runoff response and sediment yield measurements Potential evapotranspiration (PET) in the island of St. John is greater than monthly precipitation totals for most of the year. The deficit of rainfall relative to PET means that there are no perennial streams in St. John. The combination of steep slopes, shallow soils, and high intensity storms results in “flashy” runoff hydrographs with exceptionally steep rising and recession limbs. As part of the current project, a discharge and suspended sediment sampling station was installed during the 1998 field season at the former site of the USGS station in Lameshur Bay Gut. A second station was installed in Fish Bay Gut, but this was placed about 100 m downstream of the USGS site in order to capture more of the runoff and sediment from the extensive unpaved road network in the Fish Bay watershed. Stage at each of these stations is being measured at 15-minute intervals by a pressure transducer and a data logger. The data collected at these stations were used for four different purposes: 1) quantify catchment-scale water yields; 2) determine the precipitation thresholds needed to initiate runoff on these streams; 3) calculate suspended sediment yields; and 4) calculate bedload transport rates. Data from the old USGS stations in Fish Bay, Lameshur, and the still active Guinea Gut station will also be incorporated into this analysis. Both stations operated satisfactorily and complete runoff data sets were collected during the study period. Sediment Production and Sediment Transport One of the main objectives of this study is to quantify sediment production rates from different landscape units on the surface of St. John. Landscape units are defined as areas with distinct sediment production rates. In order to construct a realistic sediment budget, one must quantify sediment production rates from each landscape unit. Since it is not possible to make measurements on all units, one must develop procedures to predict sediment production rates from unmeasured sites, and these must be based on the processes that erode and transport sediment to the stream network. These procedures will be necessarily be based on empirical relationships, but the complexity of these relationships will vary according to the factors that induce erosion on the particular surface being modeled and our ability to identify and measure the controlling factors. Natural hillslopes Two different methods were used to quantify sediment production rates from natural hillslopes. The first method was to simply collect all of the runoff and sediment produced from the undisturbed plots described before. Because the volume of runoff was measured after large storms, it was relatively straightforward to also determine the amount of sediment being produced. If any sediment was observed in the bottom of the reservoir at the time of sampling, the water was agitated and a sample was collected. These samples were filtered, dried and weighed to determine the concentration of suspended sediment. The total sediment in the reservoir was calculated by multiplying the measured sediment concentration by the total volume of runoff. If there was sufficient sediment, a particle-size analysis was conducted using the hydrometer method. A small number of samples have been collected from these plots over the period covered by this report, but the lab analyses have not yet been completed. The second method to quantify erosion rates from undisturbed areas used silt fences to collect the sediment produced from unchanneled convergent areas. Three silt fences were installed in the Bordeaux Mountain area during the 1998 field season and two fences were established in the Maho Bay area in 1999. At the end of the time period included in this report no sediment had been trapped in any of these silt fences, even though overland flow had occurred in all of the areas from several high volume and high intensity precipitation events. Road surface The main objectives of the road tread component of this project were to: 1) quantify sediment production rates and the particle-size distribution of eroded materials; 2) identify the most important factors controlling erosion from the road tread; 3) build an empirically-based model of sediment production rates using precipitation data and road tread characteristics; and 4) generate data to test the applicability of other road erosion models. Road drainage area is believed to be the primary control on the amount of runoff from the road surface for a given rainfall event, while road gradient is hypothesized to be the primary control on the velocity of overland flow. The product of area times slope is commonly used as a surrogate for total shear stress. For this reason the product of road surface area and road segment slope was the primary criterion for selecting the specific road segments to be monitored within each of the three precipitation zones. Within the moderate precipitation zone we were also able to identify road segments spanning three levels of road usage, and these were abandoned roads, road segments used primarily by light vehicles, and road segments subject to high level of both light vehicles and trucks. Sediment production from road segments was measured by two different methods. The first method used silt fences at the outlet of road drainage features (i.e., culverts or rolling dips) to trap the sediment being transported from the road surface. Hence the first step towards installing the silt fences was to find sites where all the road surface runoff was being collected and discharged one location. At these sites we installed fabric dams by driving 3-feet long pieces of rebar vertically into the ground. One edge of the filter fabric was fastened to the rebar, while the other end was laid out on the ground upslope of the sediment fence. The upslope edge was then secured with rocks or with u-shaped landscape staples, and this apron upslope of the dam greatly facilitates the identification and removal of the trapped sediment. Fourteen fences were installed in 1998 and six fences were added in 1999 in order to better sample the range of factors that are expected to control road surface erosion on St. John. After the fences were installed, they were visited about every two to four weeks to check on their condition. If a measurable amount of sediment had accumulated in the fence, this was shoveled into buckets and weighed in the field. A well-mixed sample of about 2-4 kg was collected and placed in watertight bags. These samples are taken to the lab to determine percent moisture content and particle-size distribution. The field-measured weight is then corrected according to the measured moisture content. Sediment production was calculated by dividing the total dry weight by the road surface area contributing to the sediment trap. The second method to quantify road tread erosion rates was to measure runoff and suspended sediment. Suspended sediment samples at the sites were collected either manually or with a pump sampler. The collected samples were filtered, dried, and weighed. The sediment yields from each road segment were determined by multiplying the mass of suspended sediment times runoff and integrating over time. If the mass of suspended sediment was sufficient, the particle-size distribution was also determined by the hydrometer technique. Between 21 October and 16 December 1998 a total of 39 suspended sediment samples were collected from Cocoloba Trail, while 9 grab samples were collected from two different storm events in late August 1999 at the Maho Bay Camp road. Cutslopes This component of the study was designed to quantify sediment production rates from cutslopes and fillslopes. Cutslope and fillslope sediment production rates were believed to comprise only a small fraction of the total sediment produced from roads. As a result, only a relatively small portion of our efforts have been devoted to quantifying sediment production rates from these sites. In addition to directly measuring the amount of sediment produced by cutslopes, it is also necessary to know the proportion of cutslope erosion that was delivered to the stream network. The proportion of sediment delivered from cutslopes was controlled by the rate of sediment production, the distance between the sediment deposits and the inside ditch, and the transport capacity of the ditch. In order to estimate the proportion of cutslope sediment that leaves the road prism, the sediment from cutslopes had to be isolated from the sediment originating from the road surface, and this had to be done without disturbing the amount or pattern of drainage. Paved road segments provide the best opportunity to measure sediment delivery from cutslopes without altering the site conditions, and for this reason we installed silt fences to directly measure sediment yields from culvert outflows along paved roads in the Caneel Bay and Maho Bay areas. Fillslopes Fillslopes in St. John are of the sidecast type, in that they result from the sidecasting of material directly from the blade of bulldozers or graders, and there is generally no attempt to compact the material. The uncompacted surface and vegetation regrowth usually precludes the development of infiltration-excess overland flow. As a result, sediment production rates from fillslopes were expected to be minimal, and we assumed that the sediment production rates from unrilled fillslopes are similar to the sediment production rates from undisturbed planar hillslopes. Sediment transport along low-order streams The amount of sediment transported from first-order catchments was also measured with sediment traps. One such sediment trap was installed in a first-order tributary of the Reef Bay Gut during the first phase of this project, and this proved that these traps can withstand relatively large flow events from areas of approximately 0.15 km2. However, a similar trap in a second-order stream with a much larger drainage area was destroyed by high flows in October 1998. Thus we have limited this component of the study to first-order streams. During the 1999 field season two more traps were installed on first-order streams in the Reef Bay watershed, and two traps were placed on first-order tributaries of Gibney Gut, which drains northwards into Hawksnest Bay. The original trap in Reef Bay was emptied once in December 1998 and again in July 1999. No measurements had been taken from the other traps by the end of August 1999. Sediment yields in higher-order streams Sediment yields in higher-order streams were evaluated by the collection of suspended sediment samples from the gauging stations set up in Lameshur Bay Gut and Fish Bay Gut. We were also hoping to directly measure bedload transport rates, but this has proven impractical in the larger streams due to the flashy runoff and difficulty of sampling deeper, high-velocity flows associated with high discharge events. Development of GIS coverages For our GIS-based sediment routing model we needed spatially-explicit maps of the roads and stream network. For each road and stream segment we also needed to measure or be able to predict key attributes. The road network and drainage points are being mapped with a GPS unit. For each road segment we are making detailed field maps of the road drainage pattern. From these data we can calculate road drainage area, slope, and the area-slope product. We are also collecting data on the characteristics of each cutslope in order to estimate their contribution to sediment yields at each road drainage point. There is also a large field component associated with the development of the stream layer. For each stream segment we need to quantify those factors that control the sediment transport and storage capacity. Hydraulic and geomorphic parameters such as stream gradient, hydraulic radius, streambed roughness, and stream type are being determined by a combination of mapping and surveying. Empirical relationships will then be used to extrapolate these attributes to those stream segments that were not directly measured. The initial design for the road and stream coverages was developed under this project, but most of the fieldwork was conducted after August 1999.

Principal Findings and Significance

3. Preliminary Results and Analysis This following sections summarize some of the initial findings with respect to: road surface sediment production; sediment production from fillslopes, cutslopes, and paved roads; natural erosion rates from topographically convergent areas; and sediment transport and sediment delivery within the stream network. It is important to note that this analysis is preliminary, and that the representativeness of some of the data is subject to question because they were collected over a wet season with above average precipitation. Road Surface Sediment Production Annual Erosion Rates The data collected during this study provides some initial insight regarding the hypothesized controls on runoff, erosion, and sediment yields from different landscape units and at different scales. When extrapolated to annual values, the erosion rates ranged from 4 to 28 kg m-2 yr-1, and this is substantially larger than the values for road segments estimated previously. With respect to road drainage area, our original hypothesis was that larger drainage areas should generate more runoff and hence higher erosion rates. However, we determined a weak negative relationship between annual erosion rates and road drainage area. We found that the annual road erosion rate tended to increase with increasing road gradient. This is consistent with our hypothesis and erosion studies in other areas. Further analysis of the data indicated that there is a weak negative correlation between road drainage area and average slope. This means that the road segments with larger areas tended to have lower slopes, and this may help explain why the larger road segments tended to have lower erosion rates. We would expect that annual erosion rates should increase with increasing precipitation, but we found no such trend. Since the infiltration capacity and runoff rates from road segments should be relatively similar, it is clear that other factors, such as slope and traffic, are more important controls on road surface erosion rates than annual precipitation Other collected data and our field observations suggested that if road runoff is diverted to a stable ditch, road segments with large drainage areas and steep slopes may have a substantially lower erosion rate than similar road segments where the road runoff flows along the road surface. Road surface sediment production as a function of precipitation. We found that there is generally a positive relationship between the amount of sediment produced from a given road segment and precipitation. In most cases the relationship appears to be relatively linear, while for a couple of road segments the increase in sediment yield with precipitation appears to be more non-linear. The strongly non-linear relationship for one of the segments in Lameshur Bay may be due to the fact that the runoff is diverted into an improvised, unarmored ditch, and the amount of runoff is a strongly nonlinear function of the amount of precipitation. Thus the smaller rain events probably generate little runoff at the road segment scale, while the larger storms generate large amounts of runoff that can pick up much of the loose sediment left along the side of the road after grading. This discussion and our preliminary analyses indicate that the specific site conditions can greatly influence the amount of runoff and sediment production. Another issue is the potential interaction between variables, as the slope of the relationship between precipitation and sediment production tends to be steeper for those segments with a higher slope-area product. This would be consistent with the general trend but the assessment of each individual factor is again complicated by the complex interactions between factors and the inherent limitations of sample size. Nevertheless, these preliminary data suggest that, at least in some cases, segment characteristics and total precipitation can be used to predict erosion rates at the road segment scale, and these relationships should be useful for predicting the likely erosion rates for different road segments under varying meteorologic conditions. Fillslope and cutslope sediment production The data collected clearly show that road surface runoff should either be directed runoff away from the fillslopes, or that energy dissipators must be installed so that the runoff is not able to freely incise into unconsolidated fillslopes. Our results also suggest that, in some cases, cutslope sediment production rates are comparable to sediment production rates from the road surface. The delivery of this material to a road drainage location can be difficult to assess. For unpaved roads the amount of sediment that is delivered to a drainage location will depend on the location of the base of the cutslope relative to road surface flowpaths, the transport capacity and competence of the road runoff, and the particle-size

distribution of the material eroded from the cutslopes. Since most roads have an inside ditch at the base of the cutslope, much of the material eroded from the cutslopes will be delivered directly into the ditch. Hence much of the cutslope erosion is readily available for transport, and we might expect that most of the finer material will be delivered to the road drains. For paved roads we would expect an even higher delivery ratio due to the greater amounts of runoff and limited potential for sediment storage in the much smoother inside ditches. While the overall importance of cutslopes cannot yet be assessed, it is clear that they can contribute a substantially higher proportion of the road-related sediment than originally predicted. Sediment from Undisturbed Vegetated Plots The plots on vegetated planar hillslopes did not produce any measurable sediment during the project period even though several precipitation events did generate runoff. This confirms earlier assertions that sediment production rates from these areas are very. The low sediment production rates are probably due to both the paucity of runoff and the surface protection afforded by vegetation and rocks. These data are important because they provide the basis for comparison to the measured erosion rates from unpaved roads, cutslopes, and fillslopes. Sediment Delivery Rates From a First-Order Sub-Catchment and Implications for Larger Scales. The sediment trap in the first-order stream in the Reef Bay catchment provided information on the ability of small, high-gradient streams to transport the sediment being delivered to them. In this case the 0.15 km2 catchment includes a 0.58-km section of Bordeaux Mountain Road. This road is relatively steep and located at or just below the ridge that forms the upper boundary of the first-order catchment. The road drains into a swale that was probably originally unchannelled, but is now a small channel. A total of 14.1 tons of sediment were collected from this trap during the first year of this study, and this converts to approximately 94 tons/km2. If we assume that all of this sediment was derived from the road, this is equivalent to an erosion rate of 24 tons/yr per kilometer of road. Since this value is very close to the erosion rates calculated from other roads in the same area, this implies that the sediment delivery ratio for road-related sediment in these types of streams is close to unity. At a larger scale the delivery of sediment from a road to the marine environment may be affected by the path the sediment follows. We found that key controls on the rate of sediment delivery include the frequency, duration, and magnitude of runoff events, as these provide the basic transport capacity. This runoff must then be routed into and through the channel network, and the channel characteristics will influence both the transport capacity and potential for sediment storage. Educational Outreach A very important part of this project was to disseminate our findings to the public, land managers, and private landowners. A greater awareness of road erosion issues should help stimulate further actions to reduce road erosion, while the communication of our technical findings can help landowners and land managers determine the most effective use of a given expenditure. To this end we were in regular communication with organizations such as the Department of Natural Resources (DPNR), University of the Virgin Islands (UVI), Virgin Islands National Park, Biological Resources Division of the U.S. Geological Survey, Natural Resources Conservation Service, Island Resources Foundation, and Friends of Virgin Islands National Park. We also conducted a series of more formal presentations and interviews, and a partial list of these include:

- Presentation in the Water Resources Research Institute Seminar Series, UVI St. Croix Campus, 10 December 1998;
- Active participation in the DPNR Fish Bay Watershed Committee, July-December 1998;
- Conducted two field trips for the Fish Bay Homeowners Association in December 1998;
- Conducted a field trip for Chuck Weickert (Interim Chief of Resource Management for the VI National Park) and Julien Harley (Chief of Coastal Zone Management in St. John and current St. John Administrator);
- Interviewed by Amy Roberts for an article on the Tradewinds newspaper, April 1999;
- Conducted a field trip for Leo Preston, Natural Resource Conservation Service;
- Interviewed by Gail Karlsson for an article in the St. John Times, August 1999;
- Presentation to the Board of the Friends of the V.I. National Park, 1 September 2000.

Descriptors

Erosion, Runoff, Sedimentation, Urbanization, Roads.

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Mr. Ramos-Scharron's dissertation will result from this study.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

The results of this study are being prepared for possible publication.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Applicable Indicators of Risk for Coastal Waters in Tropical Environments
Project Number	D-01 (Project in Progress)
Start Date	08/01/1998
End Date	02/28/2001
Research Category	Biological Sciences
Focus Category #1	Water Quality
Focus Category #2	Wetlands
Focus Category #3	Non Point Pollution
Lead Institution	Virgin Islands Water Resources Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
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Gary A. Toranzos	Associate Professor	University of Puerto Rico	02
Javier Carrero	Student	University of Puerto Rico	03
[illegible]	Student	University of Puerto Rico	04

Loyda Mendez	Student	University of Puerto Rico	04
Yesenia Santiago	Student	University of Puerto Rico	05

Problem and Research Objectives

Evidence has been found against the use of fecal coliform bacteria as indicator organisms of fecal contamination in tropical waters due to the presence of these indicators as part of the resident microflora in these environments. There is a real need for the development of a rapid, easy, inexpensive and accurate method for assessing tropical water biological quality. Coliphages seem to be excellent alternate indicators of the biological quality of waters. If a correlation can be established between the presence of coliphages and the presence of fecal contamination we will have a more reliable method to determine the possible impact these waters have on public health. A great deal of effort is being placed on improving the biological quality of waters in tropical areas without taking into consideration the autochthonous nature of coliforms and fecal coliform. This project is focused toward water quality assessment on coastal environments of tropical islands for a one-year term. The objectives are to evaluate the reliability of coliphages as alternate indicators of fecal contamination and biological quality in tropical waters, to correlate the concentrations at which coliphages are present with the presence of currently used indicator organisms, and to promote the establishment of a long-term biological monitoring of coastal areas used for recreation.

Methodology

The following techniques represent the primary methods for this research:

- Bacteriological analyses - Samples will be analyzed by the membrane filtration technique with the use of m-ENDO for the detection of total coliforms, m-FC for fecal coliforms and m-Enterococcus agar for Enterorocci.
- Phage Assays - A direct, single-layer coliphage assay is being used. Briefly, a 100 to 200 ml volume of sample is mixed with liquefied (and kept at a temperature of 45 degrees Celsius)2X trypticase soy soft agar. The host (Escherichia coli C3000) is added, the mixture plated and incubated at 37 degrees Celsius. At six and twelve hours post-incubation, the plates are coated.
- Bacteriophage hosts - An E. coli C3000 (ATCC 15597) will be used as a host. We propose to test several strains of E. coli to sample waters for the presence of coliphages. This will be done in order to determine if there are any non-fecal bacterial viruses, which can also be detected in the environment.

Principal Findings and Significance

Several samplings have been carried out at the Luquillo Watershed area. Soil and water samples have been obtained throughout the year. From the several dozens of isolates, some were chosen at random for identification using the BIOLOG system. The results are shown below (Table 1 and Table 2). From these, several isolates identified as Escherichia coli were then subcultured to make sure we were working with pure cultures. The DNA was isolated using standard protocols and then the polymerase chain reaction (PCR) was used for the amplification of the 16S rRNA gene as shown in Table 3. The amplicons were then subjected to restriction analyses (using the ARDRA, or Amplified Ribosomal DNA Restriction Analysis, fingerprinting method) and the results are shown in Figures 1 and 2.

It becomes clear that many of the isolates are in fact E. coli, and that the fingerprinting analyses using ARDRA confirm these conclusions. We are in the process of sequencing some of the fragments generated to further confirm the findings.

We are in the process of obtaining more isolates and are also carrying out some coliphage assays as well as Clostridium spp. detection as mentioned in the proposal.

It should also be noted that two undergraduate students and one graduate student took part in this portion of the project. Ms. Loyda Mendez did the sampling and the identification, whereas, Ms. Yesenia Santiago and Mr. Javier Carrero completed the molecular characterization portions. Ms. Santiago has successfully defended her Honors Program Senior Thesis, and has already been accepted into medical school. Mr. Carrero will defend his Master's thesis and has already been accepted into the Ph.D. program at George Washington University.

TABLE 1

Coliforms	**Bacteria**
Total	*Enterobacter cloacae*
Total	*Citrobacter freundii*
Total	*Burkholderia cepacia*
Total	*Klebsiella pneumoniae*
Total	*Burkholderia solanacearum*
Total	*Citrobacter freundii*
Total	*Erwinia amylovora*
Total	*Erwinia amylovora*
Total	*Citrobacter freundii*
Total	*Erwinia chrysanthemi*
Total	*Erwinia amylovora*
Total	*Citrobacter freundii*
Total	*Erwinia chrysanthemi*
Total	*E.coli*
Fecal	*E.coli*
Fecal	*Enterobacter cloacae*
Fecal	*Citrobacter freundii*
Fecal	*E.coli*
Fecal	*E.coli*
Fecal	*E.coli*
Fecal	*E.coli*
Fecal	*E.coli*
Fecal	*E.coli*
Fecal	*E.coli*
Fecal	*E.coli*
Fecal	*E.coli*
Total	*Citrobacter freundii*

Total	*Citrobacter freundii*
Total	*Enterobacter cloacae*
Total	*Escherichia vulneris*
Total	*Pantoea agglomerans*
Total	*Erwinia amylovora*
Total	*No ID*
Total	*Erwinia chrysanthemi*
Total	*Erwinia amylovora*
Fecal	*E.coli*
Fecal	*Enterobacter agglomerans*
Fecal	*Enterobacter cloacae*
Fecal	*E.coli*

TABLE 2

Total number of identified isolates from the Luquillo Watershed	*75*
Thermotolerant Coliforms	*27*
Total Colifomrs	*48*
Escherichia.coli	*27*
Enterobacter	*17 (E.agglomerans 5, E.cloacae – 9, E.taylorae 1, E.gergoviae-1, E.hormaechei 1)*
Citrobacter freundii	*6*
Kluyvera cryocrescens	*4*
Klebsiella	*4 (K.pneumoniae 3, K.oxytoca 1)*
Erwinia	*8 (E.amylovora 4, E.chrysanthemi 4)*
Escherichia vulneris	*0*
Pantoea agglomerans	*0*
Burkholderia	*2 (B.solanacearum, B. cepacia)*
NO ID	*3*

TABLE 3. Primer sequences for the 16S rRNA gene amplification

Primer Designation	Position E. coli 16S rRNA	Sequence (5'-3')
PA	19-38	AGAGTTTGATCCTGGCTCAG
PH	1541-1561	AAGGAGGTGATCCAGCCGCA

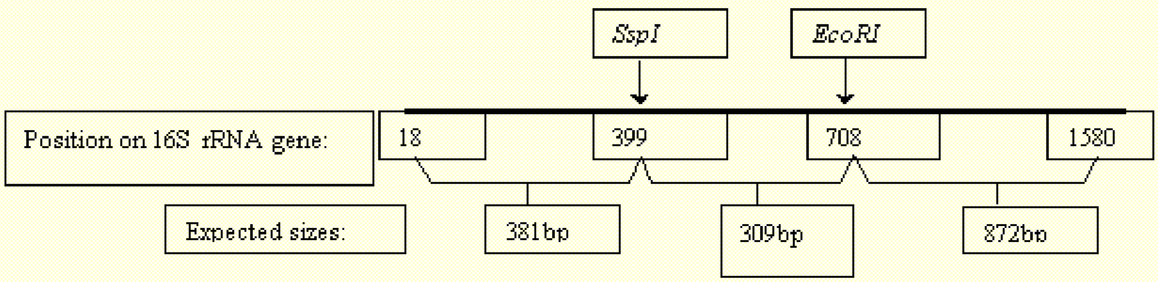

Figure 1. Restriction map for the enzymes *EcoRI* and *SspI*. Schematic representation of restriction digests of the 16S rRNA gene amplicon with the restriction enzymes *SspI* and *EcoRI*. Positions on 16S rRNA are based on the expected product of the PA/PH primers in a PCR.

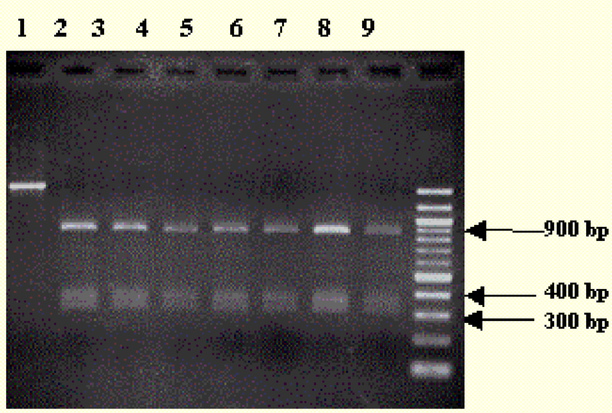

Figure 2. Restriction digest of amplicons: Lanes: 1: PCR of Colony 3EL, 2: 3EL cut, 3: 5EL(5) cut, 4: 4EL cut, 5: 27LII cut, 6: 5EL cut, 7: 7EL cut, 8: 28LII cut, 9: NEB 100bp ladder. All cuts carried out with *SspI* and *EcoRI*. Expected sizes: 309 bp, 381 bp, and 872 bp.

Descriptors

Water Quality, Biomonitoring, Coastal Zone, Bacteria, Viruses, Risk Analysis, and Water Quality Standards.

Articles in Refereed Scientific Journals

Project in Progress.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Delivery, Deposition and Effects of Land-Based Sediments on Corals in St. John, US Virgin Islands
Project Number	VI 99-01
Start Date	03/01/1999
End Date	02/28/2001
Research Category	Climate and Hydrologic Processes
Focus Category #1	Acid Deposition
Focus Category #2	Groundwater
Focus Category #3	Non Point Pollution
Lead Institution	Virgin Islands Water Resources Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Richard M. Nemeth	Assistant Professor	Virgin Islands Water Resources Research Institute	01
Henry H. Smith	Associate Professor	Virgin Islands Water Resources Research Institute	02
Lee MacDonald	Associate Professor	Colorado State University	03

Problem and Research Objectives

Over the past several decades the Virgin Islands have witnessed rapid development of inland and coastal areas. The construction of unpaved roads and removal of the natural vegetation can greatly increase erosion rates relative to natural conditions. Recent studies on St. John, U.S. Virgin Islands, have identified the network of unpaved roads on St. John as the largest source of sediment (MacDonald et al. 1997, Anderson and MacDonald 1998, Ramos 1998). Increased turbidity from clay and silt reduces light penetration essential for coral growth, while deposition of fine sediments increases coral energy costs, contributes to mortality due to suffocation, and reduces coral larvae settlement success (Rogers 1990, Roberts 1993, Sebens 1994). This load of sand, silt, and clay poses a direct threat to the health of the corals and other reef organisms (Rogers 1990, Nemeth 1998a,b). Environmental assessments are critical to evaluate the effects of land development on coral reefs. Although a number of studies have independently investigated various aspects of land practices on erosion (MacDonald et al. 1997) or the effects of sedimentation on corals (Rogers 1990), there is a lack of studies that rigorously and quantitatively link runoff and erosion processes in the terrestrial environment to the ecology of downstream aquatic systems. Such integrative studies can then provide resource managers with the data to more accurately predict the effects of increasing sediment loads on nearshore marine systems. The primary goal of this project is to directly and quantitatively link upslope sediment production from a developed (Fish Bay) and an undeveloped (Lameshur Bay) watershed to the downstream marine environment. The objectives of the terrestrial component of this project were to:

1. Evaluate the potential and amount of sediment storage along the main guts feeding into Fish and Lameshur Bays; and
2. Intensively sample the suspended sediment concentrations and runoff from the main guts feeding into Fish and Lameshur Bays.

The objectives of the marine research component were to:

1. Quantify the amount and types of sediment deposited within Fish and Lameshur bays;
2. Measure water quality within Fish and Lameshur Bays;
3. Measure coral recruitment, percent algal cover, and composition of reef fishes at three sites within Fish and Lameshur bays; and
4. Assess coral reef condition in Fish and Lameshur Bays.

Methodology

Study Sites The primary research sites are two watersheds, guts, and bays on the south side of St. John, U.S. Virgin Islands. The Fish Bay watershed is the largest watershed on St. John (6.1 km2), and it has experienced extensive road-building and development over the past 15-20 years (MacDonald et al. 1997). The Lameshur Bay watershed is slightly smaller (4.4 km2) and relatively undisturbed, as it is located almost entirely within the Virgin Islands National Park. Since the watersheds are similar in topography and Fish and Lameshur Bays are only about 5 km apart, they provide an ideal comparison with respect to their predicted sediment delivery and the comparison between reefs subjected to different rates of sedimentation. The coral reefs in both bays are located along the eastern and western shorelines and extend from inside the bays to beyond the entrance of the bays. Terrestrial Component Current and potential sediment storage in the channel network. The geomorphic assessment of current and potential sediment storage in the stream channels will be conducted along longitudinal transects from the headwaters to the edge of the bays. The gradient, bed material particle size, current sediment storage, and confinement of the channels will be assessed at regular intervals. The number and size of pools will also be assessed in each channel segment, as these represent key sites for sediment storage. The use of longitudinal surveys will also provide us with a more qualitative assessment of how sediment is currently being transported through the system. Suspended Sediment Sampling in the Main Guts. Sampling of sediment concentrations were conducted during and immediately after storm events using automated, flow-activated pump samplers located on the main Fish Bay and Lameshur guts. These data will be directly related to the amounts and particle sizes of sediment collected in Fish and Lameshur Bays. Marine Component Sediment Collection in Fish and Lameshur Bays. Sedimentation was measured using tubular PVC sediment traps (5.2 x 20.8 cm) at three reef sites along both the eastern and western shorelines of Fish Bay and Greater Lameshur Bay. Pairs of sediment traps attached to steel rebar stakes were set 10 m apart at six sites within each bay (n=12 traps/bay). Reef sites were located inside the bay, towards the mouth of the bay, and just outside the bay. This array measured rates of sedimentation along the coral tract from inside to outside the bay. Sediment traps were capped underwater and replaced every 30 to 60 days. The sediment obtained from each trap was oven dried and sieved to determine particle-size distribution and flux of terriginous sediments. Water Collection. Sea water samples were collected in 1 l plastic bottles from 1 m below the surface at each reef site (n=6) and were analyzed for turbidity (NTU) and total suspended solids (TSS, mg/l) at the Water Resources Research Institute Laboratory at the University of the Virgin Islands. Turbidity was measured with a 2100P Hach Turbidimeter and TSS was measured using pre-weighed glass-fiber filters. Coral Reef Assessment. Assessment of the coral reefs of Fish Bay and Lameshur Bay used the Atlantic and Gulf Reef Assessment (AGRA) methodology. Data included a measure of reef condition, percent cover of coral and algae, density of Diadema antillarium sea urchins, coral recruitment levels, and composition of the reef fish community. Four reef sites were selected for both Fish and Lameshur Bays. Reef sites were located inside the bay and outside the bay. Condition of corals and coral cover were measured along 10 x 1 m line transects, algal abundance and coral recruitment were measured with 25 x 25 cm quadrats and fish biomass and diversity were measured along 30 x 2 m belt transects.

Principal Findings and Significance

Monitoring stations were established on July 21, 1999. Subsequent sediment and water samples were collected on October 2 and November 22, 1999 and February 7, March 8 and May 9, 2000. These sample periods represented 73, 51, 77, 31, and 62 days, respectively. Although sampling was to be conducted on monthly intervals, the extended periods between sampling was due to several mechanical failures of our research vessel. Never-the-less some interesting patterns have emerged. Turbidity was significantly greater in Fish Bay than in Lameshur Bay ($F_{1,66}=16.62$, $p<0.0001$). In both bays turbidity decreased with increased distance from the watershed outlet ($F_{1,66}= 5.12$, $p<0.009$). Total suspended solids showed no patterns relative to monitoring locations ($F_{1,66}=0.114$, $p<0.892$), or bays ($F_{1,66}=0.002$, $p<0.968$). Seven of eight coral monitoring sites have been completed for benthic organisms to date. Evaluation of fish populations have been completed for half of the monitoring sites. Since one site has yet to be completed, statistical analyses of these data have not been conducted. In general, the primary finding was that coral cover was greater in Lameshur Bay than Fish Bay. Other patterns that emerged were percent live tissue per coral head and coral recruitment increased from the inner sites to the outer sites. The density of Diadema urchins was found to be greater inside the bay. No patterns have emerged for percent diseased or bleached corals or cover of macro algae. This project has provided support for two UVI undergraduate students. Ms. Nicole Kellum completed an independent research project and produced a report for university credit and Mr. Vernon Callwood presented a portion of the data for his senior science seminar.

Descriptors

Coastal Zone, Biomonitoring, Erosion, Sedimentation, Algae, and Fish Ecology

Articles in Refereed Scientific Journals

Project is in progress.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Information Transfer Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Information Dissemination
Description	Establishment of a Weather Data Compilation System for the Virgin islands
Start Date	03/01/1999
End Date	02/28/2001
Type	Library And Database Services
Lead Institution	Virgin Islands Water Resources Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Henry H. Smith	Associate Professor	Virgin Islands Water Resources Research Institute	01

Problem and Research Objectives

Weather monitoring agencies monitoring weather conditions in the Virgin Islands consist of both commercial and federal agencies (National Weather Service and U.S. Geological Survey). Both types of agencies are commonly centralized off-island and historical data is not readily accessible by the public. No locally situated agency exists that regularly collects weather data and makes that information available to the community. With this project the Water Resources Research Institute's objective was to remedy this situation and develop a demonstration site for a locally based agency to monitor and record weather data and act as a central location for weather data.

Methodology

Establishing Weather Monitoring System Estimates were requested from five companies capable of providing automated weather monitoring systems. Of these companies Campbell Scientific was chosen to provide the station based on their low cost, their reputation for providing quality meteorological instruments, and their software that enables users to send real-time data to the Internet. Site selection and preparation was carried out prior to the arrival of the instruments. The chosen site was at a location that facilitated radio communication between the station and WRRI's data storage computer, had relatively level terrain, and at a suitable distance from buildings and obstructions. The station set up at this site consists of a tripod support frame with guy wires for added strength and monitoring instruments and electronics secured to the frame. The instruments are a pyranometer, barometer, anemometer, wind vane, temperature and humidity probe and rain gage. A data logger located in a weatherproof enclosure controls all of these instruments and a radio modem that communicates with a data storing desktop personal computer. The station battery is continually charged by a solar panel making the station independent of the local power utility. Most instruments take measurements of weather conditions every three seconds (the barometer, being the only exception, takes a single measurement every hour). These three-second measurements are processed hourly and the output is sent to the data storage personal computer. At midnight, daily measurements and statistics are also transmitted to the personal computer. The hourly outputs of the station are as listed: 1. Array number 2. Year 3. Day 4. Time (hour: minutes) 5. Wind speed 6. Wind direction 7. Wind direction standard deviation 8. Maximum wind speed (for the hour) 9. Maximum wind speed time 10. Maximum wind speed direction 11. Average temperature 12. Average vapor pressure 13. Average solar irradiance 14. Dew point temperature 15. Atmospheric pressure 16. Relative Humidity 17. Rainfall (running total) The daily outputs of the station are as listed: 1. Array number 2. Year 3. Day 4. Maximum temperature 5. Maximum temperature time 6. Minimum temperature 7. Minimum temperature time 8. Maximum vapor pressure 9. Maximum vapor pressure time 10. Minimum Vapor Pressure 11. Minimum Vapor Pressure time 12. Maximum solar irradiance 13. Maximum solar irradiance time 14. Total rainfall 15. Total solar radiation

Principal Findings and Significance

The significance of the station is that it demonstrates to the local agencies and provides the community with ready access to current and historical weather data for both mundane and research applications.

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

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Other Publications

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	N/A	N/A	N/A	4
Masters	1	N/A	N/A	N/A	1
Ph.D.	N/A	1	N/A	N/A	1
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	5	1	N/A	N/A	6

Awards & Achievements

Publications from Prior Projects

Articles in Refereed Scientific Journals

MacDonald, L.H., R.W. Sampson, and D.M. Anderson (2000). Runoff and road erosion at the plot and road segment scales, St. John, U.S. Virgin Islands. In press, Earth Surface Processes and Landforms.
MacDonald, L.H., D.M. Anderson, and W.E. Dietrich (1997). Paradise threatened: Land use and erosion on St. John, US Virgin Islands. Environmental Management 21(6): 851-863.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Sampson, R.W. (2000). Road Runoff and Erosion at the Plot and Road Segment Scales, St. John, U.S. Virgin Islands. MS Thesis, Colorado State University, Fort Collins, CO. 164 p.