Report for 2004VI18B: Hydrology Modeling in Turpentine Run, St. Thomas

- Other Publications:
  - Kelsey, R., H. Smith, D. Porter, G. Scott and T. Siewicki, 2005, Bacterial Loading, BMP Efficiency and Hydrology Modeling Turpentine Run, St. Thomas, Water Resources Research Institute Conference, University of the Virgin Islands, St. Thomas, USVI.

Report Follows

Problem and Research Objectives

Nonpoint Source Pollution (NPS) is an important source of water quality impairment in streams, estuaries, and near coastal ocean waters throughout the United States, including the Virgin Islands (DPNR 2003A). In order to quantify loading of nonpoint source pollutants from river and stream systems, it is generally necessary to have information on both the concentration of the pollutants and the water flow that transports the pollutant into the receiving waters. Hydrologic modeling is often used to estimate river discharge and stormwater flow based on rainfall, land use, elevation, soils, and other meteorological data. Concurrent with water quality studies, these models may present a powerful tool for estimating pollutant loads.

The recent Dissolved Oxygen TMDL for Mangrove Lagoon and Brenner Bay, St. Thomas, U.S. Virgin Islands (DPNR 2003B) notes that reductions in Biological Oxygen Demand (BOD) loading from nonpoint sources within Turpentine Run Gut system will be necessary to achieve the proposed TMDL BOD limits. The development of a detailed hydrologic model would allow coastal mangers to better estimate the loading of BOD and various additional pollutants from Turpentine Run into the Mangrove Lagoon, which affect water quality of both the lagoon and Brenner Bay, two important water-bodies for fisheries and recreational uses in St. Thomas. According to the TMDL (DPNR 2003B), the Mangrove Lagoon is currently impaired for fecal coliform bacteria and dissolved oxygen (Figure 1).

Additionally, previous research in the Turpentine Run watershed indicated that rainfall in the area is highly variable over space (Table 1). Rainfall measured or estimated for one area of the island may not accurately reflect the rainfall in other portions of the island. In order to adequately describe the rainfall that drives river and stream discharge in a particular watershed, rainfall estimates must take this spatial variability into account. This project was designed to address this need by installing a spatially distributed network of rain gauges in the Turpentine Run watershed.

Project objectives include beginning the development of a hydrologic model for the Turpentine Run Watershed. Spatially explicit rainfall and flow data are being collected and used to develop the model. This project also builds upon previous data acquisition for a small part of the upper portion of the Turpentine Run watershed (Kelsey and Smith, unpublished data). In October and November 2003, a limited effort was undertaken to examine fecal coliform removal rates from a detention pond located adjacent to Weymouth Rhymer Highway, across from the entrance to the Cost-U-Less and Cinema establishments. Although the project was able to evaluate the efficiency of the pond in removing fecal coliform bacteria from stormwater runoff, the project was unable to establish an overall loading rate for the Turpentine Run system, due to the unavailability of data describing the ultimate discharge into the Mangrove Lagoon, or the impact of spatially variable rainfall. Additionally, the previous work made it clear that semi-permanent monitoring for discharge and rainfall would be necessary for long-term assessments of hydrology.

Equipment was installed to monitor rainfall and discharge at four sites within the Turpentine Run watershed and gut system. Data acquisition will be continued throughout the project extension period (to 11/30/05).

Key components of the project have included:

1. Watershed modeling from DEM data for the Turpentine Run system,
2. Site determination and equipment installation,
3. Data acquisition and management, and
4. Development of the hydrologic model.

Watershed modeling of the Turpentine Run system was performed at the GIP Laboratory at the University of South Carolina Belle W. Baruch Institute for Marine and Coastal Sciences, in Columbia, SC. Digital elevation data for the analysis were obtained for this phase of the project from the Eastern Caribbean Center Conservation Data Center at the University of the Virgin Islands. Watershed modeling was performed to identify optimal locations for the installation of the discharge and rainfall monitors by evaluation of delineated watershed boundaries and locations of intermittent streams.

Permission to gain access for personnel and to permit the installation of necessary equipment was obtained by identifying and contacting the landowners at the locations identified above. Landowners were briefed on the basic components and reasons for the project, and were asked for permission to install the equipment on a semi-permanent basis. Although access was granted for each of these sites, the process of obtaining permissions was longer than originally anticipated. Instrumentation was installed in January, 2005, necessitating an extension of the project period to collect enough data for calibration of the hydrology model. The data collection phase of this project is scheduled to continue until November, 2005.

Methodology

Watershed Modeling

Watershed modeling was conducted at the Belle W. Baruch Institute Geographic Information Processing Lab located at University of South Carolina in Columbia, SC. GIS techniques in ArcMap™ and ArcView™ were employed to develop watershed boundaries for the Turpentine Run Watershed from digital elevation data previously supplied by the Eastern Caribbean Center Conservation Data Center. The watershed was divided into approximately six portions along the linear features of the Turpentine Run Gut stream network. Outlet points for each of these sections were identified as optimal sites to place the sampling equipment. Sites chosen were adjusted slightly to improve physical access to the equipment, site security, and permission to install and access the equipment.

Site Preparation and Equipment Installation

Following identification of optimal locations for equipment installation, permission to access the sites and install the equipment was sought. Landowners were identified using parcel information and were contacted to brief them on the project. Permission was requested for project personnel to access the sites and install the necessary monitoring equipment.

Equipment was purchased after site inspection and evaluation of the physical characteristics of each location. Rain gauges installed were Global Water RG600 tipping bucket rain gauges connected to a Global Water GL400 data logger. Water level indicators installed were Global Water WL15 data-logging water level recorders. A hand-held data transfer device was purchased to allow ease of data collection and management of the sensors in the field.

Sites were chosen for their location within the watershed system of the Turpentine Run Gut, ease of access, and security. Fortunately, each location provided some measure of inherent security as a result of fences or other security devices, or was a location where visibility was very low. Landowners were helpful in choosing locations where vandalism could be reduced.

Data Collection

Data collection was begun immediately following installation of the monitoring equipment. The data logging units were configured to record rainfall and water level at one-hour intervals to conform to the requirements of the hydrologic model time step, and to preserve battery life and storage space within the data logging devices. Data was downloaded from the units to the handheld device, for transfer to a desktop unit at UVI. The data has been stored in a Microsoft Excel™ Spreadsheet for input to the hydrologic model. Following collection, data are copied from UVI to the Baruch Institute for back-up and input into the hydrology model.

Hydrologic Model Development

The WinHSPF model, within the BASINS family of modeling applications developed for EPA, was chosen for the development of the hydrologic model. The model incorporates changes in land use, loading functions, and accounts for stochastic rainfall events in estimating discharge. The model also can incorporate modules for locally derived values for contaminant loading and transport. The model will be calibrated using available meteorological data, as well as spatially explicit rainfall and flow data collected as part of this project. As the data collection phase is still ongoing, the model has not yet been calibrated with observed data.

Principal Findings and Significance

Watershed Modeling

Watershed modeling was completed using the BASINS System obtained from EPA (EPA 2004). A Digital Elevation Model (DEM) for St. Thomas was obtained from the Eastern Caribbean Center Conservation Data Center and was used to delineate watershed and sub-watershed boundaries. Outlet points were manipulated to obtain six sub-watersheds within the Turpentine Run Gut basin, such that the outlets could reflect optimal locations for water level and rain gauge instrument locations (Figure 1). Confluences of streams and existing equipment (USGS Gage Station at Mt Zion, Turpentine Run) were also taken into account when choosing locations for outlets determining sub-watershed size and locations. A stream network was created from processing the DEM to create raster data sets representing flow direction, and flow accumulation. The flow accumulation raster was reclassified to derive the stream network. The stream network was visually inspected for accuracy, and was subsequently used during the delineation of watersheds within the BASINS system.

Installation Equipment

Five water level indicators and three rain gauges were purchased and installed at the outlet points along Turpentine Run Gut (Figure 2).

Data Collection

Data collection was begun on January 13, 2005 and is scheduled to continue through November 2005 (Figure 3, and 4).

Hydrologic Modeling

The hydrologic model has been created but has not yet been calibrated with observed precipitation or flow time series data from installed instruments. Existing precipitation data obtained from nearby weather stations further indicates that accounting for the spatial variability of precipitation in this system will be important. Figure 3 shows large discrepancies between the predicted and observed discharge. These discrepancies may be attributable to several potential sources, including inaccurate precipitation data from spatial variability, or inaccurate values for other model parameters and inputs. Spatially and temporally explicit precipitation data will be useful in model calibration.

Significance

The model may be valuable to watershed and coastal mangers in assessing the loading of various pollutants into Brenner Bay and the Mangrove Lagoon (DPNR 2003B). Potential future assessments of loading rates for fecal coliform bacteria, nutrients, BOD, and sediments will be assisted by the development of such a model. Specific estimates for loading rates of these pollutants may be particularly beneficial to managers in evaluating management strategies to reduce nonpoint source pollution.

Additional benefits of the project include the support of monitoring efforts for the current Dissolved Oxygen TMDL, and the establishment of procedures necessary to develop hydrologic models elsewhere on St. Thomas and in the Virgin Islands.

A student, Paul Adjodha (UVI Class of 2005, Computer Sciences), was supported by this project. Training was provided in the areas of data acquisition and management, experimental study design, hydrology, and Global Positioning Systems (GPS) techniques. This project also was part of a lecture for "Environmental Regulation and Planning", Course Number ENHS 775 in the Environmental Health Sciences Department, Arnold School of Public Health, University of South Carolina. The guest lecturer was R. Kelsey, and the course instructor was D. Porter.

References

Division of Planning and Natural Resources (DPNR), 2003A, *Coastal Water Quality Monitoring Manual*, Accessed March 19, 2003, Available: http://www.ocrm.nos.noaa.gov/PDF/USVI_Monitoring_Manual.pdf.

Division of Planning and Natural Resources (DPNR), 2003B, *Dissolved Oxygen TMDL for Mangrove Lagoon and Brenner Bay, St. Thomas, U.S. Virgin Islands*, Draft, DPNR, St. Thomas, USVI.

Environmental Protection Agency (EPA), 2004, *Better Assessment Science Integrating point and Nonpoint Sources, BASINS Version 3.1 User's Manual*, EPA-823-C-04-004.

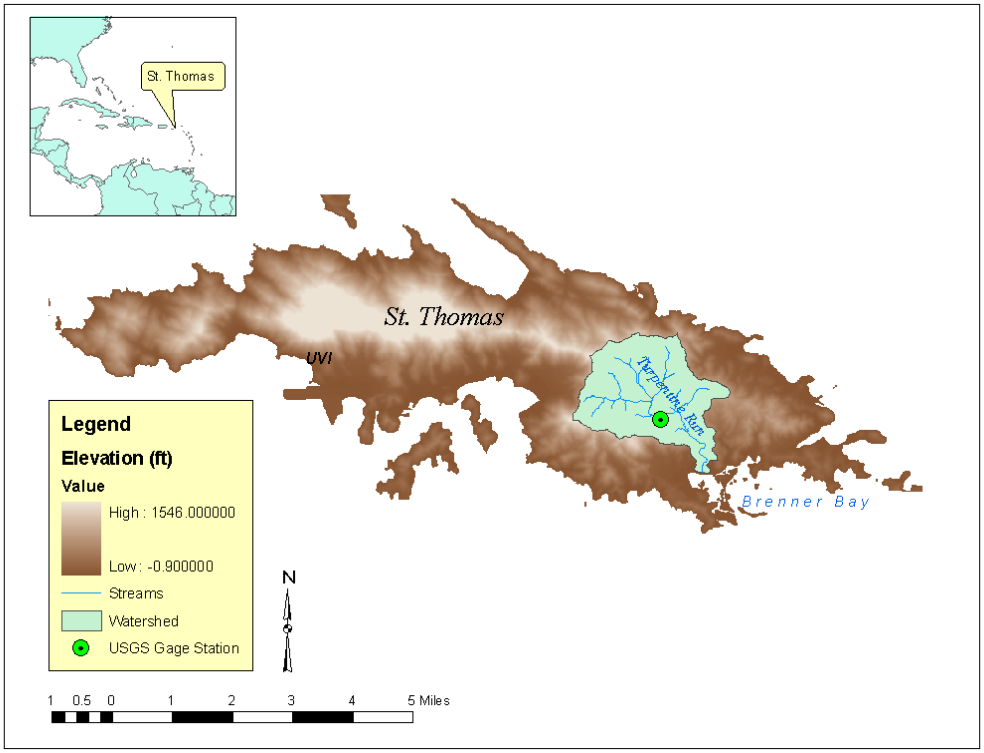

Figure 1. Study Area Location

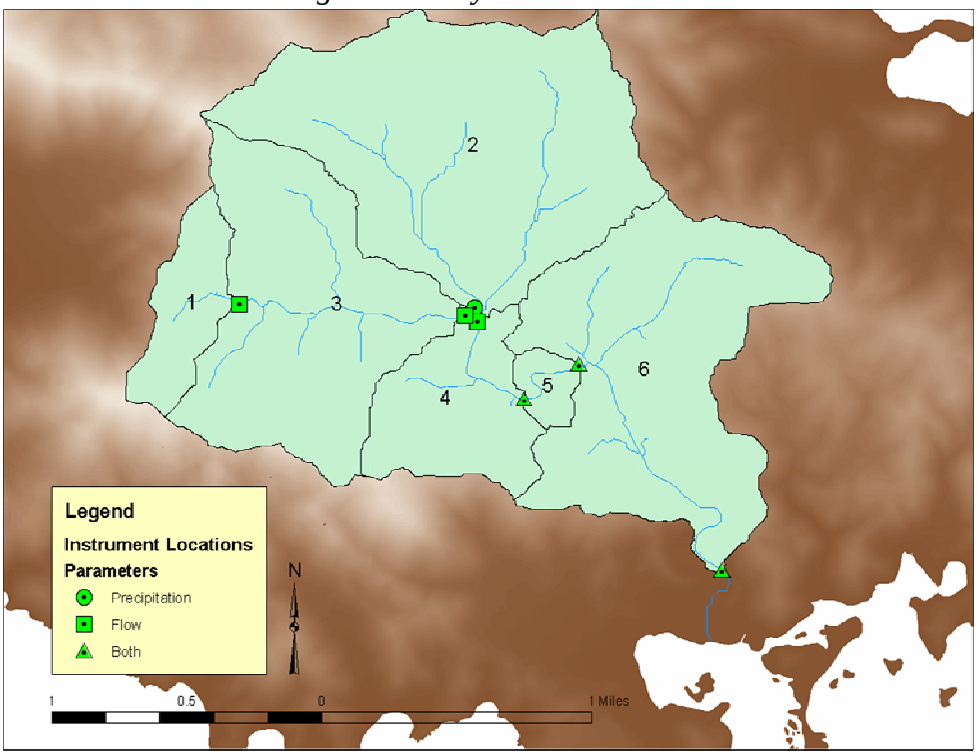

Figure 2. Location of Instrumentation and Sub-Watersheds

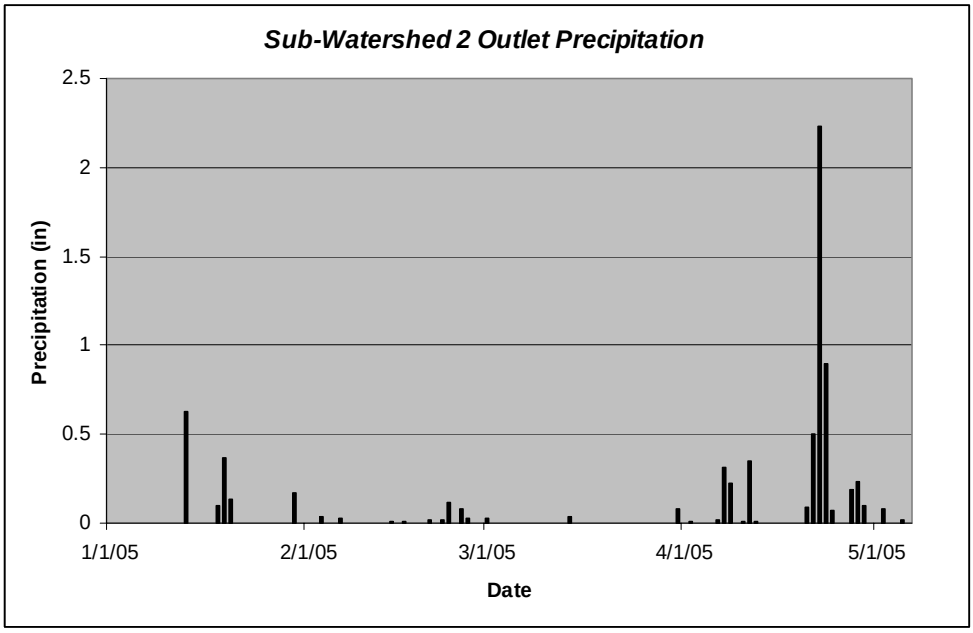

Figure 3. Example Precipitation Data

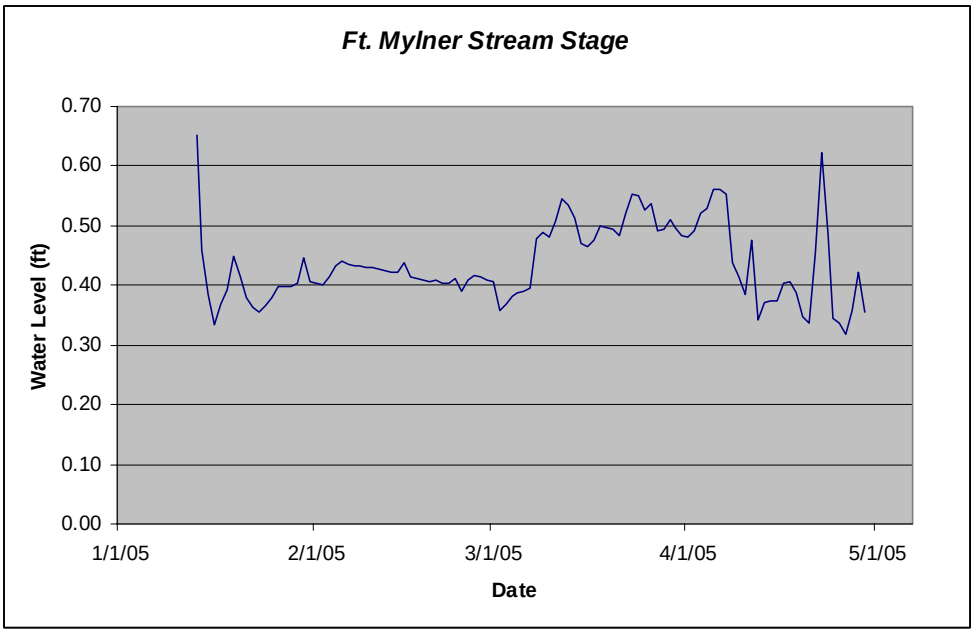

Figure 4. Example Stream Stage Data

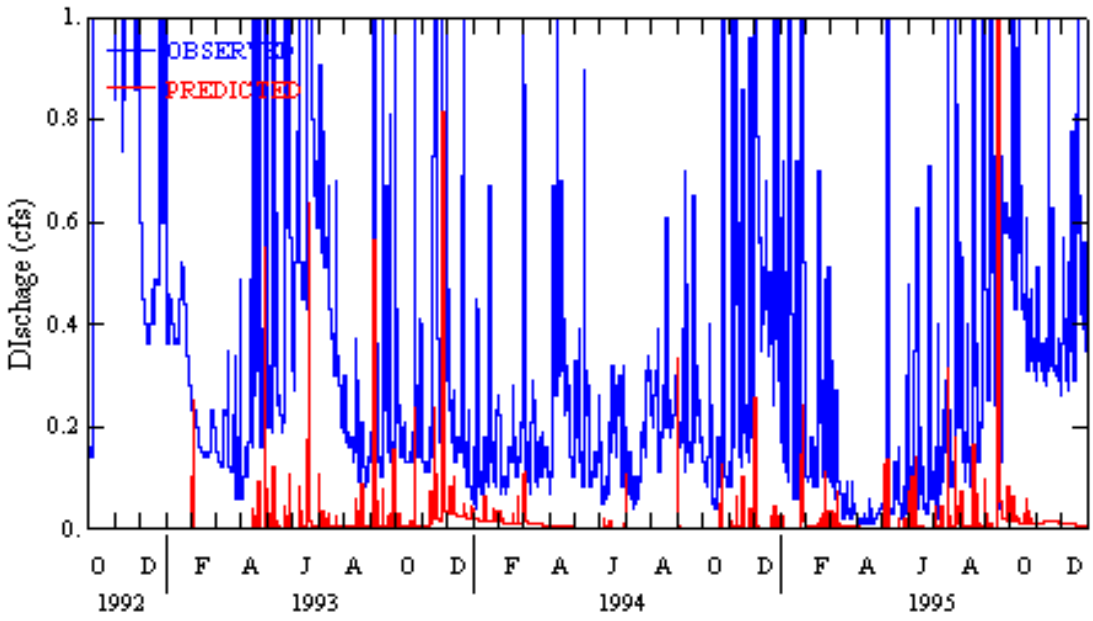

Figure 5. WinHSPF Output for Observed and Modeled Discharge at the USGS Gage Station

	Rainfall by Location (in)	
Date	UVI	Gaging Station
11/12/2003	2.09	1.78
11/13/2003	2.67	3.29
11/14/2003	4.08	2.71
11/15/2003	2.78	0.15
Total	11.62	7.93

Table 1. Selected Storm Rainfall Data 2003