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INTEGRATED WATER MANAGEMENT

Practical Experiences and Case Studies

edited by

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AN ECO-HYDROLOGICAL PROJECT ON TURKEY CREEK WATERSHED, SOUTH CAROLINA, U.S.A.

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Abstract. The low-gradient, forested wetland landscape of the southeastern United States' Coastal Plain represents an important eco-hydrologic system, yet there is a very little information available on the region's ecological, hydrological and biogeochemical processes. Long-term hydrologic monitoring can provide the information needed to understand basic hydrologic processes and their interactions with climatic variation, ecosystem processes, land use change, and other natural and anthropogenic disturbances. Monitoring also provides researchers with baseline data for evaluating responses, generating new scientific hypotheses, and testing eco-hydrologic models. This information is crucial for the sustainable management of present and future water resources in the southeastern Coastal Plain region, with its growing population, rapidly expanding development, and intensive timber and agricultural industries. This

development, and intensive timber and agricultural industries. This paper presents a multi-collaborative approach for building a monitoring and modeling framework for conducting long-term eco-hydrological studies on a 5,000 ha watershed in the South Carolina Coastal Plain.

Keywords: Low-gradient, Coastal plain, Forested wetlands, Water management, Water quality, Monitoring, Modeling, Francis Marion National Forest

1. Background

In 2004, with support from the USDA Forest Service (FS) Southern Research Station (SRS) and the National Council for Air and Stream Improvement, Inc.

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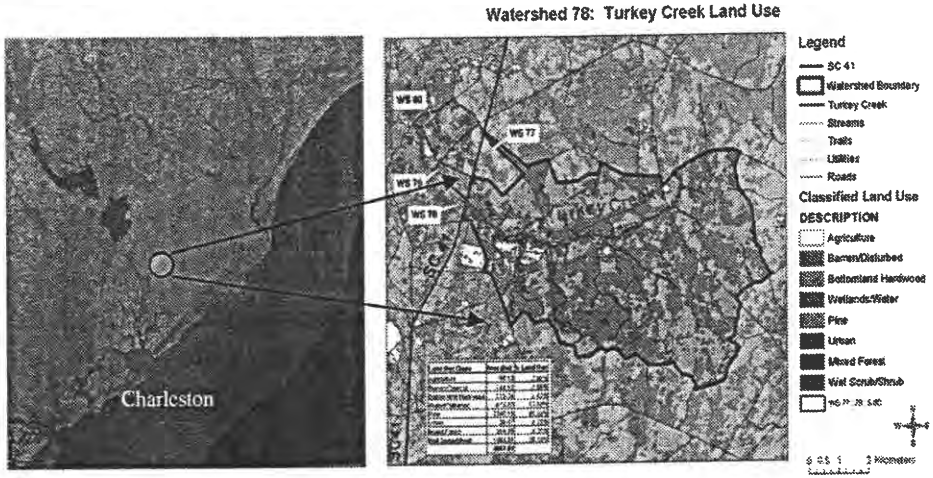


Figure 1. Coastal South Carolina and Charleston (left picture) with the location of the Turkey Creek Watershed (right picture).

(NCASI), a large-scale eco-hydrological monitoring and modeling study was re-established on a predominantly forested 5,000 ha coastal watershed at the Francis-Marion National Forest in South Carolina (Fig. 1). This revitalization effort is on the same watershed (WS 78) that was originally established by the Forest Service in 1964 and monitored until 1984 (Amatya and Trettin, 2007).

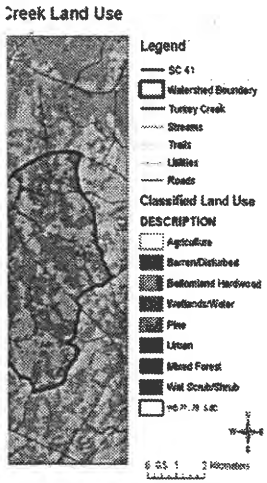
The current project includes the installation of a real-time gauging station (http://waterdata.usgs.gov/sc/nwis/uv?site_no=02172035) both for rainfall and

(http://waterdata.usgs.gov/sc/nwis/dv/site_no=02172040)
flow (Fig. 2) on a newly constructed bridge, in cooperation with the United States Geological Survey (USGS), the College of Charleston, and the South Carolina Department of Transportation. Located at the headwaters of a major tributary of the Cooper River, which drains to the Charleston Harbor System, WS 78 is typical of other watersheds in the coastal plain where development is taking place.

The goal of this project is to develop a multi-cooperative research framework for addressing critical issues of sustainability of goods and environmental services from low-gradient forested wetland landscapes, which typify the coastal plain.

2. Current Objectives

- To study the stream flow dynamics and water balance of WS78;
- To explore the potential effects of depressional areas on wetland hydrologic functions;



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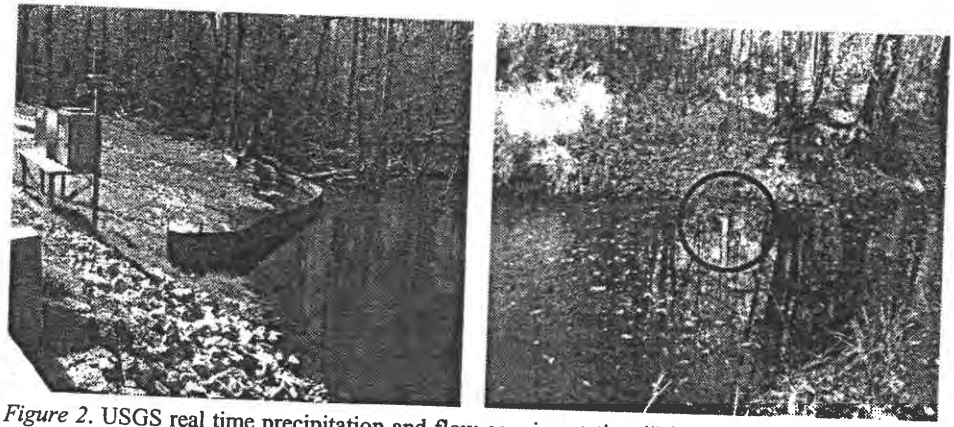

Figure 2. USGS real time precipitation and flow gauging station (# 02172035) downstream (left picture) and stage recording sensor (right picture) upstream of Highway 41 bridge at Turkey Creek watershed.

- To evaluate the stream flow dynamics before and after a Category IV hurricane (Hurricane Hugo, 1989);
- To develop Total Maximum Daily Loads (TMDLs) for identified pollutants;
- To evaluate the spatial water table and soil moisture dynamics;
- To evaluate the stream water chemistry compared to other watersheds dominated by intensive plantations, agriculture and urban areas;
- To evaluate the stream biology and biological indicators of stream health;

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- To study long-term hydrologic and water quality effects of land use change and land management practices including biomass removal and prescribed burning;
- To develop tools to communicate the values provided by healthy coastal watersheds.

3. Study Site

The third-order watershed WS 78 (e.g. Turkey Creek) with an approximate drainage area of 5,000 ha is located about 50 km north-west of Charleston, South Carolina (Fig. 1). The watershed monitoring was originally established in 1964 by installing a flow gauging station about 800 m downstream of the current gauging station. Land use within the watershed is comprised of 52% pine forest (mostly regenerated loblolly (Pinus taeda L.) and long leaf pine (Pinus palustris)), 28% wetland shrub and scrub land, 14% wetlands and water, and 6% in agricultural lands, roads and open areas (Amatya and Radecki-Pawlik, 2007). The watershed was heavily impacted by Hurricane Hugo in

September, 1989, and the forest canopy was almost completely destroyed (Hook et al., 1991). The watershed is dominated by poorly drained soils of Wahee (Clayey, mixed, thermic Aeric Ochraquults) and Lenoir (Clayey, mixed, Thermic Aeric Paleaquults) series followed by some sandy and loamy soils (SCS, 1980). The salient features of the watershed including the management practices and its recreational use are presented in Table 1.

TABLE 1. Salient Features of Turkey Creek Watershed (WS 78).

Salient Feature	Description
Location	Francis Marion National Forest near Huger, Berkeley County, South Carolina
Drainage area	~5,000 ha (50 km^2)
Hydrologic Unit	03050201
Gauging Location	WS 78 on SC Hwy 41 N (USGS Gauge # 02172035)
Datum of gage	~4.57m above sea level NGVD29
Latitude/Longitude	33°07'53" / 79°47'02" NAD27
Water and wetland areas	~670 ha (6.7 km^2)
Stream order and main stream length	Third order; 11.4 km
Elevation	3 to 12 m above mean sea level
Average annual rainfall	~1370 mm
Average annual temperature	~18.4°C
Average annual potential evapotranspiration:	~1000 mm
Average annual runoff	~330 mm
Tidal effects at the outlet	No tidal effects
Soils types	Poorly to moderately drained high water table

Soils types	soils
Major land use	Almost 94 percent on forest lands, public ownership
Forest types	Longleaf (*Pinus palustris*), and loblolly (*Pinus taeda L*), Bottomland hardwoods, Mixed pine-hardwood
Management practices	Planting and natural regeneration, biomass removal for reducing fire hazards, prescribed fire and thinning for restoration of native long leaf pine and habitat management for red-cockaded woodpeckers (*Picoides borealis*), an endangered species
Recreational uses	Hunting, fishing, bird watching, hiking, canoeing, historical tours, horse riding, all-terrain vehicle (ATV) trails

4. Approach

The most effective way to address scientific questions and management challenges relative to water resources is through collaborations among academia,

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industries, State and Federal government agencies, private landowners, and non-governmental organizations. Activities based on long-term monitoring capacity include projects to build and share a long-term eco-hydrological database, identify and prioritize new issues, conduct laboratory and field monitoring and modeling studies, and implement the recommended science and technology using appropriate science delivery approaches.

The monitoring approach includes initiation of measurements of basic eco-hydrological parameters such as precipitation, weather (air temperature, relative humidity, wind speed, and solar radiation), water quality (nutrients, physical and chemical parameters), and ground water table depths. Building upon this basic foundation, collaborative efforts will expand the scope and complexity by adding studies on mercury cycling, aquatic community composition and dynamics, carbon and green house gas fluxes, forest community and dynamics.

Similarly, Geographical Information Systems (GIS) based spatial data on topography, hydrography (drainage network), soils, vegetation, land use, and land management are being developed for the watershed. Spatial data based on a LIDAR (Light Detecting and Ranging) based technology will also be explored for accuracy and verification. A physically-based spatially distributed watershed eco-hydrologic model will be constructed using these data. The simulation model will be calibrated and validated using temporal and spatial data on precipitation, weather, stream flow rates, and ground water table for its application to evaluate management decisions related with anthropogenic and natural disturbances.

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4.1. DEVELOPMENT OF THE COLLABORATIVE MONITORING PROGRAM

The Center for Forested Wetlands Research (CFWR) at Southern Research Station initiated the work by collaborating with Tetra-Tech, Inc., an Atlanta-based firm, in data sharing and database development. CFWR installed a Campbell Scientific CR10X complete weather station to monitor air temperature, humidity, wind speed, and solar radiation in the middle of the watershed (Fig. 3). The College of Charleston installed deep piezometers (Fig. 4) in December 2005 to assess surface-subsurface flow interactions. Stream water quality sampling station has recently been installed through a cooperative effort between the Forest Service CFWR and USGS (Fig. 5). Water samples are being analyzed for carbon and nutrients at the CFWR's Soil Chemistry laboratory in Charleston, South Carolina.

Multiple shallow water table wells have also been recently installed across the watershed in cooperation with the Francis Marion National Forest (FMNF) to examine rainfall-water table relationships and water table and soil moisture

Figure 3. Campbell Scientific CR10X Weather station in the middle of the Turkey Creek watershed.

Figure 4. A set of deep piezometers near the weather station on the Turkey Creek watershed.

dynamics as affected by soil types and vegetation, and to validate models. Biologists at FMNF are planning to conduct monitoring for fish biota in the main stream and its tributaries.

There is also a growing interest in conducting research on Hg pollution in South Carolina coastal plain. Mercury in wet soils and wetlands has the potential to be converted into methyl-mercury, which through bioaccumulation through the food chain, may affect or even be lethal to fish and bird species. As the Turkey Creek watershed has a large area of wet soils and wetlands, the

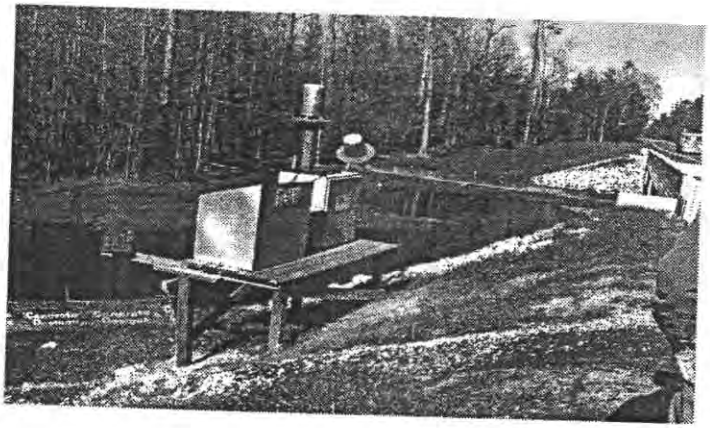

Figure 5. ISCO water quality sampler (front) connected with the USGS real time rain/flow recording Sutton datalogger (back).

considerable potential for initiating a Hg cycling study is being explored with prospective collaborators.

5. Recent Studies on this and Adjacent Watersheds

Re-establishing the Turkey Creek Watershed as a gauging network on the 3rd order stream completes the establishment of 1st (WS 77 and WS 80), 2nd (WS 79) and 3rd (WS 78) order streams (Fig. 6) allowing researchers, land managers

Turkey Creek watershed.

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and planners to evaluate the water budgets, effects of land use change or other disturbances on stream flow, nutrient export, and other ecological processes at multiple scales. Development of watershed hydrologic research on this and the adjacent smaller scale watersheds was outlined elsewhere (Amatya and Trettin, 2007). Long-term hydro-meteorologic data on the two first order watersheds (WS 77 and WS80) (Fig. 6) are made available for data sharing at *http://lterweb.forestry.oregonstate.edu/climhy/harvest.pl.*

A key factor in developing the large-scale watershed monitoring collaboration is the development and application of work at smaller scales. The following are accomplishments, which helped facilitate the development of work at the larger scale:

- Initial studies on stream flow dynamics of the watershed compared to two other adjacent 1st and 2nd order watersheds at Santee Experimental Forest (Fig. 6) using historical data have been conducted in collaboration with the Agricultural University of Krakow, Poland (Amatya and Radecki-Pawlik, 2007).

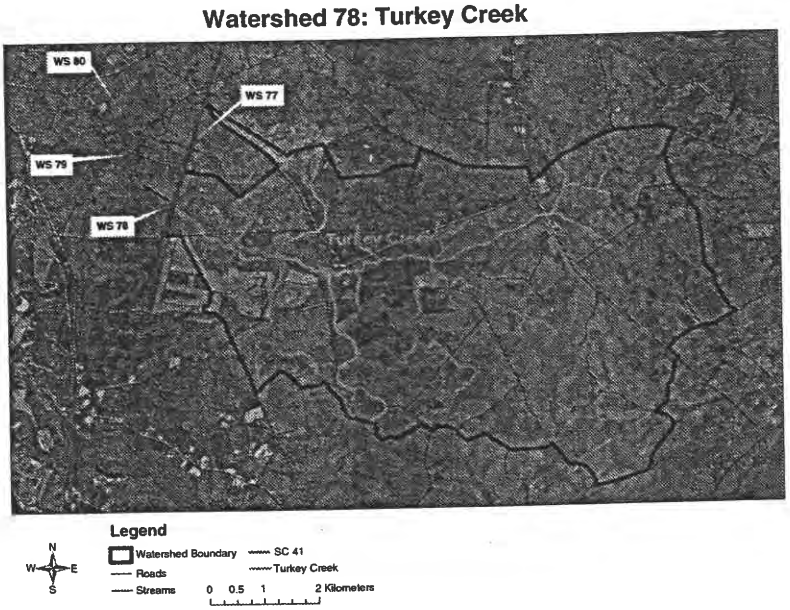

Figure 6. Layout of 1st (WS 77 and WS 80) and 2nd (WS 79) order watersheds within USDA Forest Service Santee Experimental Forest located adjacent to the 3rd (WS 78) Turkey Creek watershed.

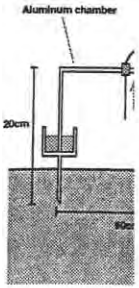

Figure 7. Schema
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- Harder et al. (2007a) recently reported a short-term water budget for an adjacent 1st order watershed (WS 80).
- Harder et al. (2007b) tested DRAINMOD (Skaggs, 1978) model on the 1st order watershed (WS 80) to further evaluate its long-term water budget.
- Wilson et al. (2007) reported effects of Hurricane Hugo in 1989 on the stream outflows and the nutrient exports of the WS 80.
- Other past studies prior to the year 2000 on the first-order watersheds are described by Amatya et al. (2005).

6. Ongoing Studies

- JJ&G Engineering and Tetra-Tech, Inc. are using historic data from the watersheds to develop a water quality model of the Charleston Harbor System for the Berkeley-Charleston-Dorchestor Council of Governments (Lu et al., 2005).
- A study on green house gas carbon dioxide (CO_2) and methane (CH_4) emissions from riparian wetlands of the watershed is currently ongoing (Fig. 7).

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7. Planned S

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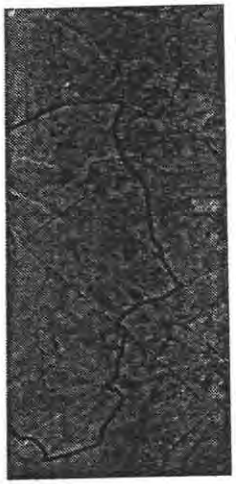

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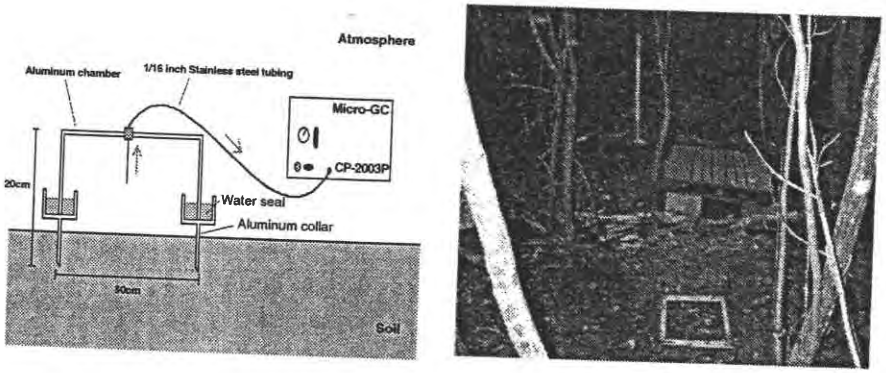

Figure 7. Schematic of a static chamber used to collect and measure trace gas fluxes (left) and the installation at the site (right) on Turkey Creek watershed.

- Another study evaluating the effects of depressional areas on wetland hydrologic functions is underway in cooperation with Florida A&M University.
- A study to examine the effects of biomass removal using thinning followed by prescribed burning both on a plot and a watershed-scale has just begun on the 1st (WS 77, WS80) and 2nd (WS 79) order watersheds (Fig. 6).
- Information on hydrology, meteorology, hydrogeology, geomorphology, topography, hydrography, soils, landuse, land and water management practices, stream water quality, and ecology are being

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water quality, and ecology are being prepared and analyzed together with watershed socio-economics for Turkey Creek basin management plan to be published in the second volume of the NATO/CCMS Integrated Water Management Pilot Workshop Science Series.

7. Planned Studies

- CFWR has initiated a collaboration with the Berkeley-Charleston-Dorchester County of Governments, Clemson University, and the College of Charleston for a potential Total Maximum Daily Load (TMDL) study on fecal coli form bacteria in a portion of the Turkey Creek stream.
- Collaborative efforts are underway to test and apply existing GIS-based distributed hydrologic models (SWAT (Arnold et al., 1998), DRAINWAT (Amatya et al., 1997; 2004)) to simulate the water budget, stream flows, surface and subsurface water yields, soil moisture, water table depth, and

nutrient and sediment loadings as affected by year-to-year variations in climate, as well as forest management practices including harvesting and prescribed fire.

8. Other Potential Collaborative Activities/Studies

Project collaborators have been meeting regularly about twice a year to review the progress and identify issues and funding sources to address them through collaborative studies. Examples of other works being considered, which demonstrate the value of a multi-institutional collaboration for large-scale eco-hydrologic monitoring include:

- Continuous monitoring of water quality for nutrients, sediment, and physical parameters (dissolved oxygen (DO), pH, temperature, turbidity, conductivity) and validation of stream water quality models;
- Monitoring for Hg and fecal coli form bacteria;
- Monitoring of tidal effects and salinity levels below the watershed outlet;
- Monitoring all or part of the Quinby Creek watershed adjacent (south) to Turkey Creek for the baseline data needed to evaluate planned developmental impacts;
- Surveys of Turkey Creek stream biology and morphology;
- Surveying for crayfish and freshwater mussels in wetlands within Turkey

Creek and other areas in the region;

- LIDAR (Light Detection and Ranging) surveys of the Turkey Creek area for refining the watershed boundaries;
- Mapping of hydric soils and more recent land use/land cover;
- Analysis of pre- and post- Hurricane Hugo stream flow;
- Prediction of spatial distribution of moisture at various locations on the watershed;
- A more detailed water budget, including estimates of evapotranspiration;
- Cumulative effects of land management practices;

9. Benefits

Field studies and modeling applications will be an important resource for management decisions and monitoring assessments on the Francis Marion National Forest and other large tracts of forest land. They should also serve as reference eco-hydrologic units for comparison with more intensively managed forests and/or developed lands in the Coastal Plain, or for assessing allowable

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loading or discharge criteria. We hope that the historical and the new databases generated from studies on this watershed, including our long-term hydrologic research facilities at the Santee Experimental Forest, can increase the level of collaboration and our collective abilities to address many water resource issues facing the Southeastern United States and similar other regions around the world. With the watershed's location at the headwaters of the Cooper River and Charleston Harbor, the data collected will also be useful for evaluating additional water quality and quantity issues in downstream areas with tidal effects.

10. Research Collaborators

USDA Forest Service, Southern Research Station (SRS)
National Council for Air & Stream Improvement, Inc. (NCASI)
USDA Forest Service, Francis Marion National Forest
US Geological Survey
College of Charleston
South Carolina Department of Transportation
Agricultural University of Krakow, Poland
JJ& G Engineering
Tetra-Tech, Inc.
Florida A&M University

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