Quantifying Hydrologic Impacts on Spatio-Temporal Variability of Stream Water Quality in Coastal Louisiana

Basic Information

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Principal Investigators:	Vijay P. Singh, Y. Jun Xu

Publication

1. 1. Singh, V.P., Flow Routing in Open Channels: Some Recent Advances. Proceedings, River Flow 2004, held June 23-25, 2004, in Naples, Italy, 2004.
2. 2. Singh, V.P., Applications of Fluid Mechanics in Hydrology and Environmental Engineering. Recent Advances in Fluid Mechanics, Proceedings of the 4th International Conference on Fluid Mechanics, held July 20-23, 2004, in Dalian, China, edited by F. Zhuang and J.C. Li, pp. 29-40, 2004.
3. 3. Singh, V.P. and L. Zhang, Stochastic Dependence Modeling in Environmental Hydrology. Proceedings, International Conference on Hydraulic Engineering: Research and Practice, October 26-28, 2004, Indian Institute of Technology, Roorkee, India, pp. 46-59.
4. 4. Singh, V.P. and Zhang, L., Multivariate Stochastic Hydrologic Analysis. Proceedings, International Workshop on Watershed Management in Dry Areas: Challenges and Opportunities, January 4-6, 2005, Djerba, Tunisia, 2005.

Problem and Research Objectives

Louisiana is naturally blessed with an abundance of aquatic systems, including bayous, rivers, lakes, and aquifers, which provide Louisiana's citizens with fishing, hunting, boating, and recreational opportunities and contribute to the state's wealth and economic growth in agriculture and fisheries. While the state has more surface water available for its current use (84%) than any other state in the U.S., rapid urbanization and intensive agricultural and forest practices have increased the potential for reduction in the quality of the state's surface waters. Studies on hypoxia in the northern Gulf of Mexico have shown that an average midsummer hypoxic zone of 8,000-9,000 km^2 during 1985-1992 increased to 16,000-20,700 km^2 during 1993-2001 on the Louisiana/Texas continental shelf (Rabalais & Turner, 2001). This 3-fold increase of hypoxic zone over a relatively short period of time has been attributed to the increase of river-borne nutrients that can exacerbate coastal water eutrophication, favor harmful algal blooms, aggravate oxygen depletion, and alter marine food webs (e.g., Rabalais et al., 2002). The northern Gulf of Mexico is found to be the second largest zone of coastal hypoxia in the world (Rabalasis et al., 2002). This oxygen-depleted phenomenon is attributed to nutrient enrichment in the waters of the northern Gulf of Mexico, and it is especially profound from spring through late summer. Agriculture is considered as a major source of nutrient enrichment from the Mississippi river basin (Burkart and James, 1999; Ferber, 2001; Howarth, 2001; Winstanley, 2001; Snyder, 2001). Atmospheric deposition of nitrogen is seen as another significant source to nitrogen limited estuaries and coastal waters (Paerl et al., 2002).

In January 2001, an action plan with the major goal of reducing nitrogen discharge through Best Management Practices from the inland water into the Gulf was cleared by the state, tribal, and federal agencies and delivered to Congress (US EPA, 2001). The action plan recognizes a 30% nitrogen load reduction that is required to ensure a reduction of 5-year running average of the Gulf hypoxia zone to less than 5,000 km^2 by 2015. While this action plan called for an implementation of BMPs based on voluntary, incentive-based subbasin strategies, several key questions that will influence the success of this plan remained unanswered:

- How effective are the current BMP guidelines in protecting stream water quality from agricultural and forest activities?
- How feasibly and accurately can we provide estimates for subbasin nitrogen discharge based on the current water quality monitoring networks, especially for the areas on the lower coastal plains that have a very flat topography?
- To what extent do hydrological and hydrometeorological conditions, such as rainfall and temperature, affect the variability of coastal inland stream water quality?

These questions were addressed in this project.

A recent study by Thomson et al. (2002) reported that rainfall deficits accumulated since 1998 in Louisiana have culminated in a twofold increase in the mean annual salinity in the Lake Pontchartrain estuary. Using monthly measurements selected from 25 subbasins in Louisiana over a period of 1978–2001, Xu (2003) showed that the nutrient loads, total suspended solids, and dissolved oxygen concentrations all varied widely in the monitored streams and across seasons. However, monthly routine monitoring seems to work well for characterizing base flow

conditions, but may not be appropriate to characterize rapidly changing conditions in response to storm events. An understanding of hydrologic influences on water quality indicators at the watershed scale is apparently needed, and such an understanding is especially critical for the coastal regions of Louisiana where storm weather occurs throughout the year.

This proposed project assessed the relationship of stream water quality changes with hydrological and hydrometeorological conditions in Louisiana's six major basins close to the Gulf of Mexico. The project utilized existing long-term water quality data, hydrometeorological data, and stream discharge data maintained by Louisiana Department of Environmental Quality, Southern Regional Climate Center, US Geological Survey, and US Army Corps of Engineers. Information on land use activities and timber harvesting from the watersheds was also gathered to investigate the magnitude of hydrological influences on water quality under various land use activities. Specifically, the project had the following objectives:

1. To investigate the space-time variability of water quality indicators in the major stream/rivers on Louisiana's lower coastal plain;

2. To determine the interrelationships between water quality variability and hydrometeorological regime, such as storm weather conditions, rainfall intensity, and temperature fluctuation;

3. To identify the linkage between water quality variability and hydrological regime, such as base flow, peak flow, and groundwater recharge; and

4. To assess the impacts of land use activities on water quality of the coastal streams, wetlands, and estuaries in Louisiana under various hydrologic conditions.

Methodology

This project utilized existing long-term datasets collected from six coastal basins in Louisiana. Despite a large number of studies conducted on water quality in Louisiana's shore of the Gulf of Mexico during the past 2 to 3 decades, little knowledge has been actually gained about the impacts of hydrological and hydrometeorological variability on the dynamics of water quality indicators, even though it is inarguable about the ultimate role of hydrology on water quality. Many studies have been conducted, and many are being conducted on various aspects ranging from restoration of bottomland forests to microbiology of the coastal estuaries, inland streams and bayous; There exists a large amount of data that has not yet been fully analyzed, whereas USGS and LDEQ continue collecting water quality and streamflow data in Real-Time across the state's rivers and bayous.

To achieve its objectives described above, this project accomplished the following tasks:

1. Gathered existing water quality, stream discharge, and climatic data from all monitoring stations within the Atchafalaya, Barataria, Calcasieu, Mermentau, Terrebonne, and Vermillion-Teche river basins;

2. Identified spatial and temporal characteristics in water quality and hydrological and hydrometeorological conditions in the drainage basins;

3. Assessed the variability of annual nutrient loads and sediment runoff in relation to the variability of hydrological and hydrometeorological conditions; and

4. Utilized GIS and geostatistical techniques to determine land use impacts on water quality changes under hydrometeorological conditions across the landscapes.

Thus, the project involved the development of statistical analyses of hydrometeorologic, hydrologic and water quality data. Specifically, these included (1) analysis of variance, (2) identification of probability distributions, (3) determination of trends, and (4) development of prediction models relating hydrologic and hydrometeorologic conditions to space-time variability of stream water quality under a variety of land use changes. These models determined critical areas of water quality deterioration and the causes-land use and anthropogenic, and industrial. This information will be pivotal to defining BMPs.

Principal Findings and Significance

This research provided critical insights into the interrelationships between hydrological conditions, land use and the water quality of inland streams, wetlands, and coastal estuaries in Louisiana. The knowledge gained from this research contributes to developing site-specific TMDLs and applicable water quality standards, facilitating the assessment of the BMP effectiveness in protecting water quality in Louisiana's coastal watersheds, and helping improve the water quality monitoring strategies, all of which contribute to supporting the state's economic wealth and health of its citizens. Furthermore, the project and its results will be introduced in several Hydrology and Water Quality courses at LSU, immediately benefiting both graduate and undergraduate students in learning how science applications solve real world problems.

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Information Transfer Program

One of the Institute's objectives is to make research results available to the general public and to interested researchers and institutions through publications and other information transfer activities. Although the information transfer component of the budget of Section 104 funds is relatively small (10%), LWRRI attempts to meet this goal in many ways which include actively participating in conferences and workshops, distributing summaries and other Institute information to the public and governmental agencies, maintaining internet access and web sites, and maintaining a library of water research materials. The Institute requests that its investigators participate in reporting and information transfer activities such as publications in professional journals, workshops, and seminars.

The Institute's information transfer program is a subset of its administration program. Assisting with LWRRI's information transfer activities are two undergraduate student workers, a program coordinator (part-time LWRRI support), one research associate (half-time LWRRI support), and the associate director, Dr. John J. Sansalone. Two research associates are also available to assist in information transfer activities of the Institute. The Director, Dr. John Pardue, attends the annual National Institutes of Water Resources meetings in Washington, D.C., to discuss Institute and Program activities.

Further assisting in information transfer, the Engineering Incubation Research Center (EIRC) has given LWRRI access to image processing, GIS, and computing systems. This access provides the Institute with the necessary tools to transfer information in visual graphic format, utilize Internet resources, and develop state-of-the-art presentations. Because of the Institute's expanding development, more emphasis is being placed on updating the public and other organizations about activities and objectives using electronic media and presentation tools.

The Institutes staff continues to maintain emphasis on acquainting Louisianas research community with the research-funding opportunities through the U.S. Geological Survey Section 104 research program. 104 G program announcements, Mississippi SE-TAC RFPs, and Section 104 RFPs were widely distributed (113+ email addresses and 127 regular mail addresses, totaling 240) to Louisiana colleges and universities and to research organizations throughout the state. In addition, public announcements were made at professional and faculty meetings to encourage wide participation in the program. We send out notifications of meeting and events for the American Water Resources Association, The Capital Area Ground Water Conservation Committee, and the Louisiana Rural Water Association.

In addition, our organization is contacted regularly with various questions for the public and/or private sector concerning water issues; we try to connect these people with the proper experts within our organization and the broader academic community. We have built a comprehensive web portal LAWATER.com in conjunction with the LWRRI web site to help facilitate this effort. **LAWATER** is a new portal website developed by LWRRI designed to bring together the diverse web resources dealing with water resources in Louisiana for use by water professionals, researchers, students and other stakeholders. In addition, LAWater is directly linked with LWRRIs digital water library project which is providing electronic copies of all of the published Bulletins from the Institute, dating back to 1966.

LA Water is divided into 4 general areas, each addressing a specific area of interest for Louisianas water resources. These are: Water Quality Water Quantity/Supply Flooding/Hazards Coastal Restoration, with a focus on freshwater diversions One focus of LAWater is centralizing the real-time resources available on the web. These include USGS stream gauge data for discharge, DEQs statewide ambient water quality

data, LSUs WAVCIS system and other resources. In addition, LAWater provides lead stories on each page, directing you to timely information or articles impacting Louisianas water resources. We want LAWater to be a service to the public and water professionals across the state. Web site: http://www.lwrri.lsu.edu LAWATER: http://www.lawater.lsu.edu

Under the direction of our director, the Institute has developed a new branding symbol for all of the information transfer activities and publications and is reconstituting the newsletter. Our annual report is housed at the Louisiana State Archives, Hill Memorial Library at LSU, and is available online at the Institutes web site.

In response to the focused RFP for the 2004-2005 solicitations, we received 3 new proposals and funded 1 of those after advisory board review. In addition; two of the projects from the previous fiscal year submitted phase II of there projects and were funded after advisory review. The theme, selected in consultation with faculty and advisory board members, is focused on characterizing particulates for heavy metals in aquatic systems using non-invasive spectroscopy and tomography. In addition, a continuing interest in total maximum daily load (TMDL) calculations in Louisiana water bodies is being maintained.

NIWR-USGS Student Internship Program

The Louisiana Water Resources Research Institute did not have any students in the formal NIWR-USGS Intern Program during this reporting period. The Institute maintains both formal and informal relationships with the Baton Rouge office through part time employment of students not in the intern program, and the USGS District Chief serves on the Institute Advisory Board. During this reporting period we have undergone a series of discussions with the state USGS office on rapidly expanding our participation in the student intern program. At the time of this report, those discussions have not been finalized.