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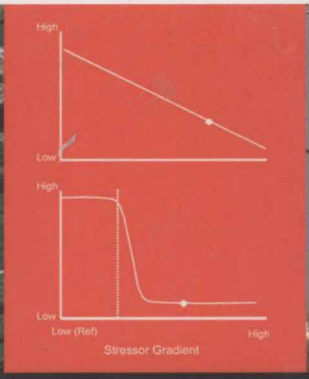
WETLAND AND WATER RESOURCE MODELING AND ASSESSMENT

A Watershed Perspective



Edited by Wei Ji

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A Watershed Perspective

Integrative Studies in Water Management and Land Development

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Robert L. France

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Foreword: A Wider View of Wetlands

There are few landforms that have been treated with the same degree of distrust, distaste, disdain, and destruction as have wetlands (e.g., R. France, ed. 2007. *Wetlands of Mass Destruction: Ancient Presage for Contemporary Ecocide in Southern Iraq*). Part of the reason for this comes about from the reality that we both literally and figuratively do not quite know where we stand in relation to wetlands; they are neither land, nor water, but exist as some uncomfortable nether region situated between the two (R. France, ed. 2008. *Healing Natures, Repairing Relationships: New Perspectives on Restoring Ecological Spaces and Consciousness*). Our language also reflects the pejorative view that much of society has of wetlands, for who has not felt "swamped" at one time or another by being "bogged" down through having too much work due to being "mired" in details?

The present volume, edited by Wei "Wayne" Ji, offers a counterpoint to such a gloomy worldview. Wetlands as described in these pages are shown to be very much centers of hydrological and ecological importance in the landscape, a view that would have certainly found resonance with that nineteenth-century wetland enthusiast, Henry David Thoreau (R. France. 2003. *Profitably Soaked: Thoreau's Engagement with Water*). And it is here, with its overall message of demonstrating the cardinal need to reinsert wetlands back into their landscape, where the present book succeeds most admirably. Wetlands are not isolated entities but rather influence, and are in turn influenced by, a vast variety of environmental and anthropogenic factors (R. France. 2003. *Wetland Design: Principles and Practices for Landscape Architects and Land-Use Planners*). In order to preserve the environmental integrity of wetlands it is necessary to circumvent the strange imbalance that exists between the scale at which wetland losses are felt by society and the scale at which wetlands have traditionally been studied or managed. The present book, *Wetland and Water Resource Modeling and Assessment: A Watershed Perspective*, anchors the goal of holistic management in a firm scientific grounding.

The bulk of the chapters in the present volume originated from a conference. Editor W. Ji took the wise step, however, as taken in several other volumes in this series (R. France, ed. 2002. *Handbook of Water Sensitive Planning and Design*; and R. France. 2008. *Handbook of Regenerative Landscape Design*), to actively solicit contributions from others who did not present at the conference in order to better address the book's overall objective. The result is a well-rounded whole with the myriad subjects being truly catholic in scope, including, for example, various spatial mapping approaches, hydrological models, ecological appraisals, and water quality and biogeochemistry investigations, many directed toward understanding threats on wetlands posed by climate change and water imbalances, chemical contamination and eutrophication, and land-use alterations and soil erosion, to name just a few. In

this respect, the present book is a worthy addition to the aspirations of the series Integrative Studies in Water Management and Land Development by Taylor & Francis. In the end, it is only by recognizing the essentialness of a watershed approach for understanding and managing landscapes (e.g., R. France, ed. 2005. *Facilitating Watershed Management: Fostering Awareness and Stewardship*; R. France. 2006. *Introduction to Watershed Development: Understanding and Managing the Impacts of Sprawl*) that wetlands can be properly assessed and modeled, as the collective voices of the authors reiterate time and again within these pages.

Finally, the international scope of the present volume is worth noting — an additional attribute of this series whose previous books have featured case studies from North America, Southeast Asia, and much of Europe, in addition to Australia and Brazil. The majority of this volume's authors originate from China, also the location of much of the research contained herein. Perhaps this should not be surprising. The Chinese have long recognized the multifaceted importance of wetlands. For example, I begin chapter 1, "Foundations," in my primer *Wetland Design: Principles and Practices for Landscape Architects and Land-Use Planners* (W.W. Norton, 2003) with the following sentence: "Early in the last millennium, a Chinese military commander retired to the old picturesque town of Suzhou. There, by drawing water from one of its famous canals, he created a marvelous garden retreat for emotional and spiritual peace . . . [the] *Chanlang ting* (Pavilion of Blue Waves)." The present book continues this foundational tradition, in this case emphasizing the importance of viewing wetlands in a watershed perspective.

Robert L. France
Harvard University

Preface: Toward a Watershed Perspective

This is a book about the methods and geospatial techniques for modeling and assessing wetlands and water resources at the watershed scale. As background, I would like to start with a brief introduction with an example from Poyang Lake. Situated in Jiangxi Province, it is the largest freshwater lake in China, with many marshes, grasslands, and alluvial floodplains in its watershed. The wetland area of Poyang Lake Basin has diverse flora and fauna and provides important habitats for many migratory birds. As a wetland of international importance (referred to as "Poyanghu" on the Ramsar List of Wetlands of International Importance, 1992) with a unique land use history, Poyang Lake has attracted great attention, domestically and internationally, from research and conservation organizations. In 2004 the Chinese Ministry of Education established a facility for lake and watershed research—the Key Lab of Poyang Lake Ecological Environment and Resource Development, which is housed in Jiangxi Normal University. The lab soon became very instrumental in attracting scientists and scholars for collaborative research. Between June 27 and 30, 2005, the lab organized and hosted a productive academic meeting at Jiangxi Normal University: The International Conference on Poyang Lake Complex Environment System and Advanced Workshop on Watershed Modeling and Water Resources Management. This event attracted scholars and professionals from China, North America, and Europe, who presented research findings and technical developments related to issues in wetland and water resource science and management.

Many of the papers presented at that conference are included in this book. However, the book is not simply the conference proceedings. The editorial advisory board selected the conference papers and also invited papers from recognized experts in order to better present the theme of the book. All submissions were peer reviewed and the best of them appear in this volume.

The theme of the book, wetland and water resource modeling and assessment, is an active field of research that constantly undergoes theoretical and technical innovations. This book emphasizes a watershed perspective in the modeling and assessment areas. The term *watershed* means a geographic area where water drains into a body of water such as a river, lake, or wetland. Other terms are often used to describe the same concept, such as *river basin*, *drainage basin*, and *catchment area*. Since the early 1990s, *watershed management* or the *watershed approach*—coordinated resource planning and management based on hydrologically defined geographic areas—has been promoted as a common strategy of water resource stewardship and other related environmental activities. In 2000 the U.S. Departments of Agriculture and the Interior announced a unified policy to protect water quality and aquatic ecosystems on federal lands. The policy serves as a framework for land and resource management focused on watersheds. This policy has been supported

by the U.S. Departments of Commerce, Defense, and Energy; the Environmental Protection Agency; the Tennessee Valley Authority; and the U.S. Army Corps of Engineers. Similar trends have occurred on other continents. For example, a pilot study on integrated water management, launched by NATO/CCMS (North Atlantic Treaty Organization/Committee on the Challenges of Modern Society) in 2002, was conducted through a series of workshops involving representatives from the NATO countries. While I was traveling in the Biebrza National (wetlands) Park in Poland in the summer of 2006, I had the good fortune to participate in part of this pilot study's sixth workshop held there. I was impressed by the vision and breadth of the study for implementing water management based on the "river basins" across Europe. Within Jiangxi Province, China, the surface water of approximately 95% of its land drains into Poyang Lake through several major rivers. The hydrological feature of this watershed is quite unique and important to water resources, biology, ecology, and socioeconomic development in the region. Thus, the watershed perspective in the research and management of the Poyang Lake ecosystem has a long tradition.

Sound watershed-based water resource planning and management should rest on scientifically justifiable data and innovative technical tools. Thus, assessment and modeling of key processes of terrestrial and aquatic ecosystems are crucial to the success of watershed management, which is becoming, as demonstrated in the studies included in this book, an active field of research and technical development. With a watershed perspective, ecosystem assessment and modeling commonly possess the following major characteristics: (1) Sufficiently large spatial scales in data collection and analysis in order to encompass major watershed features. This often leads to using remote sensing and GIS (geographic information system) for data acquisition and integration, as well as for spatial analysis. (2) Inclusion of landscape features in order to appropriately characterize watershed hydrological processes and related ecosystem components. This usually requires relating land cover and land use dynamics to water features. (3) Linking assessment or modeling results to management decisions for specific objectives. This often results in the development of decision support tools to facilitate ecosystem assessment under various management scenarios and criteria. These characteristics of watershed assessment and modeling can be found in many of the studies included in this book.

The book is divided into five parts. Part I focuses on geospatial methods and technologies. It includes four research projects on improving remote sensing methods for wetland mapping, which has comprised a fundamental yet challenging area of study for detecting wetlands at a watershed level. The chapters in this part cover topics ranging from expert system techniques for improving the remote sensing identification of wetlands (Torbick et al.; Cai and Chen), to the use of hyperspectral imagery in identifying salt marshes (Yang et al.), to remote sensing spectral techniques for vegetation mapping (Chen et al.).

Part II concentrates on wetland hydrology and water budget. McNulty et al. use a modeling framework to assess the interannual water supply stress over the next 40 years across the southern United States as a function of climate, groundwater supply, and population change. Focusing on the red-soil hilly region of Poyang Lake basin, the work of Dai et al. illustrates the characteristics of temporal distribution of a water budget, which helps us understand the occurrence of seasonal droughts and to adopt

better measures to increase water use efficiency. The chapter by Sun et al. is based on a synthesis of existing worldwide literature on the relations between forestation and watershed hydrology. It identifies the factors affecting hydrologic responses to forestation and discusses the potential hydrologic consequences of large-scale, vegetation-based watershed restoration efforts in China. Carried out in the Xing Feng Catchment within the Zhujiang Watershed, the study by Wen et al. introduces the use of a modified TOPMODEL to simulate streamflow and distinguish subsurface stormflow from the baseflow. The chapter contributed by Croley and He provides a description of the development and application of a spatially distributed, physically based surface/subsurface model of hydrology and water quality, which is used to evaluate both agricultural nonpoint-source and point-source pollution loadings at the watershed level.

Part III addresses issues relating to water quality and biogeochemical processes at the watershed scale. In their chapter, He and Croley introduce the application of the model introduced in Part II in the Cass River Watershed, a subwatershed of the Saginaw Bay watersheds in the Great Lakes area, to estimate the potential of nonpoint-source pollution loadings. The chapter by Gui et al. demonstrates the use of SWAT, an existing watershed assessment model, to simulate changes of nutrients at a temporal scale of one hundred years in Honghu Lake Basin, China. The work of Varnakovida et al. describes the construction of a model to predict total nitrogen, total phosphorous, and total suspended solid concentrations in lakes based on surrounding land cover and land use types and patterns.

Part IV is devoted to issues of wetland biology and ecology. The chapter by Li et al. introduces a method of predicting annual soil losses in Xiushui Watershed in Jiangxi Province using integrated data concerning precipitation, topography, soil, and vegetation cover with GIS. Lougheed et al. describe an investigation that develops and tests field-based methods for the rapid assessment of wetland conditions in Muskegon River Watershed, Michigan. In their chapter, Guo and Chen introduce a geospatial techniques–based method of deriving appropriate indicators for analyzing ecological conditions in Poyang Lake Watershed. Focusing on the feeding habitat of the endangered Siberian crane wintering at Poyang Lake, the chapter by Wu et al. propose a conceptual framework for integrating a model of plant biomass with remote sensing and GIS methods to simulate the growth and biomass of one submerged aquatic species under various hydrological conditions. Qi et al. present new research that expands traditional remote sensing to acoustic sensing. Their goal is to improve our knowledge about the usefulness of acoustic signals as a means to measure and interpret ecological characteristics of a landscape—the soundscape.

Part V features innovative development and applications of wetland assessment and management methodologies. The chapter by Ji and Ma covers the research, development, and application issues concerning geospatial decision models for assessing wetland vulnerability to human impact at a watershed scale. They provide prewarning information for regulatory wetland management decision making. Using the study of Muskegon River Watershed in the Great Lakes Region as an example, Stevenson et al. contribute a chapter on a conceptual framework of watershed science. It comprehensively reviews and discusses watershed science as related to its essential role in watershed management, its complex nature and the solutions for

complex watershed problems, and its implementation in a multidisciplinary and collaborative framework. Also dealing with Muskegon River Watershed, Wiley et al. demonstrate the development of a GIS-based approach that uses ecologically defined valley segment units to integrate a landscape transformation model with a variety of hydrologic and other models for assessing risks to key watershed resources under various scenarios. The major thrust of the chapter by Yu et al. is a discussion of recent advances in watershed management technology for nonpoint source pollution control. It also discusses a number of issues that should be addressed before implementing watershed pollution-source control measures.

The contributors include senior scholars and young researchers. All of the chapters were peer reviewed. Hayley Charney at Michigan State University helped edit some of the chapters. As the editor of the book, I thank all of the reviewers for their time and dedicated work, which made this book infinitely better. I want to recognize the crucial role of the Key Lab of Poyang Lake Ecological Environment and Resource Development of the Chinese Ministry of Education at Jiangxi Normal University in organizing the international conference and the workshop in 2005, that contributed many chapters to the book. I am pleased that this book has been selected for the Integrative Studies in Water Management and Land Development book series, and am honored that Dr. Robert France at Harvard University, the series editor, has written the foreword for it.

Wei "Wayne" Ji

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Editor

Dr. Wei "Wayne" Ji is a professor of geosciences at the University of Missouri, Kansas City (UMKC). He has taught courses in geographic information systems (GIS), remote sensing, biogeography, and landscape ecology at UMKC since 1999.

Over the past 25 years, his research has focused primarily on the study of water environments using geospatial methods. At Peking University, China, he completed his master's thesis focusing on remote sensing of water quality. His PhD dissertation research at the University of Connecticut developed a new model for coastal bathymetry with satellite remote sensing as well as a GIS for coastal mapping. In the 1990s he conducted research at the National Wetlands Research Center of the U.S. Geological Survey, where he studied innovative geospatial methods for wetland ecosystem restoration and management in Louisiana and south Florida. During that period he developed a decision support GIS for wetland value assessment modeling for coastal wetland restoration planning, and a prototype decision support GIS for wetland permit assessment. Dr. Ji also proposed a decision modeling method for integrating the results of computer simulations of wildlife species for evaluating effects of different wetland restoration scenarios.

With the support of the U.S. Environmental Protection Agency, his recent research focused on geospatial decision models for assessing wetland vulnerability to potential human impacts, for application to urban wetland studies. In addition to the wetland issues in the United States, Ji has a long-term interest in the Poyang Lake Watershed in China—a wetland area of international importance. With a U.S. Fulbright senior scholar award for research in Germany, in 2006 he surveyed wetlands and collected related research information in the coastal areas of Germany, Poland, and the Netherlands in order to understand the impact of the historical east–west division of that region on coastal resources, especially wetlands. In addition to wetlands, Ji also studied long-term landscape effects of urban sprawl in metropolitan Kansas City, GIS-based methods for assessing the conservation status of wildlife genetic diversity through a case study in the southern Appalachians, and spatial distributions of wintering birds in the lower Mississippi region.

Dr. Ji has served as a manuscript reviewer for many academic journals and a proposal reviewer for agencies like NASA and the U.S. National Science Foundation. He was the guest editor for *Marine Geodesy*'s 2003 special issue on marine and coastal GIS. He is an associate editor of *Wetlands* — an international journal published by the Society of Wetland Scientists.

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