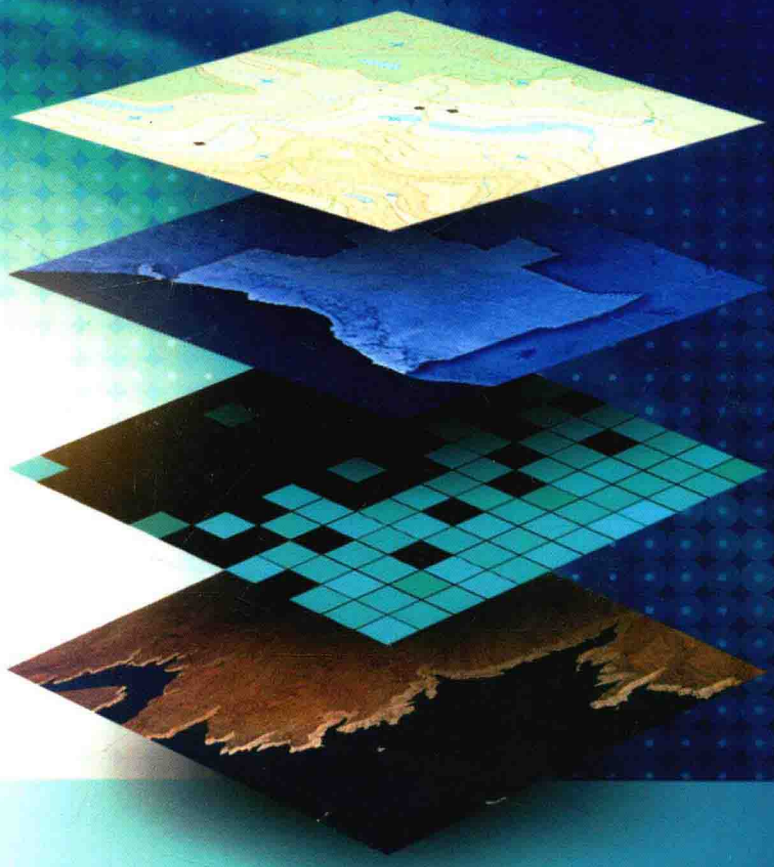
Barnali Dixon | Venkatesh Uddameri

GIS and Geocomputation for Water Resource Science and Engineering



AGU
American Geophysical Union

WILEY

GIS and Geocomputation for Water Resource Science and Engineering

Barnali Dixon
University of South Florida Saint Petersburg
Venkatesh Uddameri
Texas Tech University

AGU American Geophysical Union
WILEY

This edition first published 2016 © 2016 by John Wiley & Sons, Ltd.

Registered office: John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial offices: 9600 Garsington Road, Oxford, OX4 2DQ, UK
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

The right of the author to be identified as the author of this work has been asserted in accordance with the UK Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book.

Limit of Liability/Disclaimer of Warranty: While the publisher and author(s) have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. It is sold on the understanding that the publisher is not engaged in rendering professional services and neither the publisher nor the author shall be liable for damages arising herefrom. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

Library of Congress Cataloging-in-Publication Data

Dixon, Barnali.
GIS and geocomputation for water resource science and engineering / Barnali Dixon and Venkatesh Uddameri.
pages cm
Includes bibliographical references and index.
ISBN 978-1-118-35414-8 (cloth) – ISBN 978-1-118-35413-1 (pbk.) 1. Watershed management–Data processing. 2. Water resources development–Data processing. 3. Geographic information systems–Industrial applications. I. Uddameri, Venkatesh. II. Title.
TC413.D59 2015
628.10285–dc23

2014046085

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image:
000003542317 – © beright/iStock
000026490630 – © FrankRamspott/iStock
000035475364 – © hakkiarslan/iStock
000018287328 – © mirjanajovic/iStock

Typeset in 9/11pt TimesTenLTStd by SPi Global, Chennai, India
Printed and bound in Singapore by Markono Print Media Pte Ltd

1 2016

Barnali Dixon dedicates this book to her son, Edgar, her joyful challenge!!

Venkatesh Uddameri dedicates this book to three very special women–his grandmother (Late Sarojamma Kudthini), his mother (Late Lalitha Devi Uddameri), and his wife (Elma Annette Uddameri) for their love, support, and encouragement.

Preface

Geographic information systems (GIS) have had a tremendous impact on the field of water resources engineering and science over the last few decades. While GIS applications for water resources can be traced back to the 1970s, increased computational power, particularly of desktop computers, along with advances in software have made GIS widely accessible. Water resources engineers and scientists seek to model the flow of water, suspended and dissolved constituents in geographic entities such as lakes, rivers, streams, aquifers, and oceans. Geographic description of the system of interest is the first step toward understanding how water and pollutants move through these systems and estimating associated risks to human beings and other ecological receptors. As GIS deals with describing geographic entities, they are used quite extensively in conceptualizing water resources systems. GIS offer spatially coded data warehousing capabilities that are not found in regular database software.

In addition to data storage, retrieval, and visualization, a wide range of computations can be performed using GIS. Geoprocessing tasks such as clip, union, and joint can be used to slice, dice, and aggregate data, which facilitates visualization for pattern recognition and identification of hot spots that need attention. GIS can be used to delineate watersheds, the basic unit for hydrologically informed management of land resources. In addition to qualitative data visualization, GIS software come with a variety of geostatistical and interpolation techniques such as Kriging that can be used to create surfaces and fill in missing data. In addition, these tools can be used to map error surfaces and assess the worth of additional data collection. GIS software also come equipped with a wide range of mathematical and Boolean functions that allow one to manipulate attributes and create new information. Closed-form analytical expressions can be directly embedded into GIS systems to simulate system behavior and visualize the response of hydrologic systems (e.g., a watershed) to natural (climate change) and anthropogenic (urbanization) factors. Most of this functionality can be carried out using built-in functionality and without resorting to any programming. In addition, GIS software come with back-end programming support, which can be used to automate geoprocessing tasks, write new functions, and add additional capabilities for hydrologic analysis. The inclusion of time has been a holy grail of GIS research. Recent software enhancements and database models allow the inclusion of time stamped data and create animations that depict how the system has changed over time, allowing one to visualize over the entire space-time continuum. The idea of performing water resources computations and modeling within the GIS framework is referred to as **geocomputation** and is the primary focus of this book.

The book is written to be as self-contained as possible and is intended as a text for GIS-based water resources engineering or science courses suitable for upper-level undergraduate and early graduate students. It can also be used as a supplemental text in undergraduate and graduate level courses in hydrology, environmental science, and water resources engineering, or as a stand-alone or a supplemental text for an introductory GIS class with an understanding that the book's focus is strongly on water resources issues.

The book assumes some basic understanding of hydrologic processes and pollutant fate and transport that is covered in an introductory hydrology and environmental engineering/science class. Working knowledge of computers, particularly familiarity with spreadsheets, is also assumed on part of the reader. However, no prior experience in GIS is assumed. Elementary programming experience is desirable and will be beneficial to follow some advanced material in the book, but not required for the most part.

The book is arranged in three parts – The first part presents the fundamentals of geoprocessing operations and building blocks for carrying out geocomputations. The second part discusses the applied aspects of using GIS for developing water resources models. The third part is a compilation of case studies that illustrate the use of GIS in water resources and environmental applications. These case studies can be directly used as projects in classes or modified for other geographies. The case studies are also intended to help students transition from obtaining information from textbooks to that contained in the journal articles. Datasets for several exercises and case studies are provided on the website for the textbook, which serves as a useful companion to accompany this text.

While the focus of this textbook is largely on fundamental geocomputing concepts, we recognize the importance of software programs to implement these ideas in real-world applications. While we do not endorse any commercial product per se, we have adopted the ArcGIS software platform (ESRI Inc., Redlands, CA) for most examples in this book as it is widely used and generally accepted as the industry standard. We recognize the growing prominence of open-source GIS software and its importance in underdeveloped and developing nations. As such, we have presented a few examples of using such software as well. In particular, the availability of geospatial packages within the open-source R statistical and programming environment greatly helps with the integration of water resources modeling and GIS.

This book represents a true collaboration between an environmental scientist/geographer and a civil engineer focused on water and environmental issues. We both bring nearly two decades of

此为试读,需要完整PDF请访问: www.ertongbook.com

our experience with GIS and its use in water resources engineering and science. Our goal in writing this book was to blend the right amount of theory and practice into a single compendium. We each have taught classes on GIS in Water Resources and came to realize that while excellent texts exist on GIS as well as water resources engineering, there is not a text that blends the two. This limitation is often seen as a hindrance by students who are trying to grasp GIS (whose learning curve is admittedly steep) and trying to make connections to concepts learned in their introductory hydrology and environmental science classes. The book seeks to facilitate the learning process for water resources scientists and engineers by showing them the usefulness of GIS and geocomputation while reinforcing their concepts of hydrology and water resources. The book should also be useful to practitioners who are often required to learn GIS on the job.

We are greatly indebted to our teachers who taught us GIS and water resources and our students and research assistants who helped us learn new skills and techniques and showed us new ways of using GIS in our teaching and research. In particular, Drs. Vivek Honnungar, Sreeram Singaraju, and Annette Hernandez contributed significantly to several case studies and helped with organization of the material. Ms. Julie Earls and Mr. Stephen Douglas are thanked for their assistance with data download from public domain and background research when needed. Ms. Tess Rivenbarkt and Mr. Johnny Dickson are thanked for their comments on the material and their assistance with proofreading. We are also thankful to our collaborators in industry and regulatory agencies who have helped us understand the role of GIS in real-world applications. In particular, Mr. Tim Andruss, at Victoria County Groundwater Conservation District, is acknowledged for his support and fruitful discussions on using GIS in real-world settings.

A great deal of information on GIS, particularly the use of software, can be found on the Internet. We want to salute those unsung champions who have shared their knowledge, answered queries, and presented solutions on GIS forums that are a great resource to those working in this area. The production team at Wiley-VCH deserves special recognition for their patience and support throughout the publication process. We are also thankful to an anonymous reviewer whose suggestions greatly improved this work. Finally, we cannot thank our families enough for putting up with our craziness before, during, and after writing this book. Their assistance with proofreading of the chapters and discussing ways to improve our presentation were invaluable to the process. We do however take the sole responsibility for any errors and omissions in the text. We hope you will find the information presented here useful and welcome your feedback and comments on ways to improve our content and presentation.

Barnali Dixon
St. Petersburg, FL

Venkatesh Uddameri
Lubbock, TX

About the Companion Website

This book is accompanied by a companion website:

www.wiley.com/go/dixon/geocomputation

The website includes:

- Case studies
- Exercises

List of Acronyms

Abbreviation	Details
AAE	Average absolute error
ACRIMSAT	Active Cavity Radiometer Irradiance Monitor Satellite
ACWPP	Arroyo Colorado Watershed Protection Program
ADEQ	Arkansas Department of Environmental Quality
AF	Attenuation factor
AFC	Attenuation factor calculator
AFY	Acre-feet per year
AHP	Analytical Hierarchy Process
AI	Artificial intelligence
AIC	Akaike's information criterion
ANFIS	Artificial Neuro-Fuzzy Information Systems
ANN	Artificial Neural Networks
AOI	Area of interest
AP	Apparent color
ASCII	American Standard Code for Information Interchange
ASMC	Antecedent soil moisture conditions
ASR	Aquifer storage and recovery
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASV	Autonomous surface vehicles
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible InfraRed Imaging Spectrometer
AWRC	Arkansas Water Resources Center
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BCF	Billions of cubic feet
BD	Bulk density
BGIS	Basin Geomorphic Information System
BIL	Band interleaved by line
BMPs	Best Management Practices
BOD	Biochemical oxygen demand
CAD	Computer Aided Design
CART	Classification and regression trees
CC	Correlation coefficient
CCN	Certificate of convenience and necessity
CEC	Cation exchange capacity
CERL	Construction Engineering Research Laboratory
CERP	Comprehensive Everglades Restoration Plan
CHIPS	Colonia Health, Infrastructure, and Planning Status
CI	Convexity index
CN	Curve number
COAV	Class-object-attribute-value
CSA	Clay settling area
CWA	Clean Water Act

DBMS	Database management system
DCIA	Directly connected impervious area
DEDNM	Digital Elevation Drainage Network Model
DEM	Digital elevation model
DFA	Discriminant function analysis
DGN	Design file
DGPS	Differential GPS
DLG	Digital line graphs
DO	Dissolved oxygen
DOM	Dissolved organic matter
DOQQs	Digital Orthophoto Quarter Quads
DOQs	Digital Orthophoto Quadrangles
DRASTIC	Aquifer vulnerability index: **D**epth to water table, **R**echarge, **A**quifer media, **S**oil type, **T**opography, **I**mpact of vadose zone, **C**onductivity
DSM	Digital surface model
DSS	Decision support systems
DTM	Digital terrain model
E/ET or ET/EV	Evaporation/evapotranspiration
EDAP	Economically distressed area program
EF	Ecological Fallacy
ELM	Everglade Landscape Model
EMC	Event mean concentration
EMR	Electromagnetic radiation
ENVI	Environment for Visualizing Images
EPA	Environmental Protection Agency
EROS	Earth Resources Observation and Science
ESA	European Space Agency
ESRI	Environmental Systems Research Institute
ESSP	Earth System Science Pathfinder Program
ESTDM	Event-based spatiotemporal data model
ET	Evapotranspiration
ETJ	Extraterritorial jurisdiction
ETM	Enhanced Thematic Mapper (Landsat)
ETM+	Enhanced Thematic Mapper Plus
FAC2	Fraction of predictions within a factor of two of observations
FAVA	Florida Aquifer Vulnerability Assessment
FAWN	Florida Automated Weather Network
FB	Fractional bias
FD	Fractal dimension
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
FEMA	Federal Emergency Management Agency
FFNN	Feedforward neural network
FGDC	Federal Geographic Data Commission
FLUCCS	Florida land use and cover classification system
FMG Info Atlas	Info Atlas for Bay of Fundy, Gulf of Maine
FORTRAN	Formula Translation
FWRI	Fish and Wildlife Research Institute (Florida)
GAM	Groundwater availability modeling
GCDs	Groundwater Conservation Districts
GCM	Global climate model
GCPs	Ground control points
GeoTIFF	Georeferenced Tagged Image File Format
GIRAS	Geographic Information Retrieval and Analysis System
GIS	Geographic Information Systems
GOCE	Gravity field and steady-state Ocean Circulation Explorer
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning system
GRACE	Gravity Recovery and Climate Experiment
GRASS	Geographic Resources Analysis Support System

GRDC	Global Runoff Data Center
GRS	Geodetic Reference System
GUI	Graphical User Interface
GUS	Groundwater ubiquity score
GWVIP	Groundwater Vulnerability Index for Pesticides
HABs	Harmful Algal Blooms
HAL	Health advisory level
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center River Analysis System
HMS	Hydrologic Modeling Systems
HRUs	Hydrologic Response Units
HSG	Hydrologic soil group
HUC	Hydrologic unit code
HUC#	Hydrologic Unit Catalog number
I&O	Index and overlay
ICA	International Cartographic Association
IDL	Interactive Data Language
IDW	Inverse distance weighted
IFOV	Instantaneous field of view
IFSAR	Interferometric synthetic aperture radar
IGWV	Intrinsic groundwater vulnerability
IR	Infrared
IRS-1C or IRS-1D	Indian Remote Sensing satellites
ISCGM	International Steering Committee for Global Mapping
IT	informational technology
JPEST	Java-based Pesticide Screening Toolkit
KDD	knowledge discovery in a database
KNRIS	Kentucky National Resource Information System
LAI	Leaf area index
LHS	Latin-hypercube sampling
LiDAR	Light Detection And Ranging
LPI	Leaching potential index
LR	Logistic regression
LRGV	Lower Rio Grande valley
LSU	Louisiana State University
LU	Land use
LULC	Land use/ Land cover
MADM	Multiattribute decision making
MAGI	Maryland Automated Geographic Information System
MAUP	Modifiable Area Unit Problem
MB	Mega Bytes
MCDM	Multi-criteria decision making
MCL	Maximum concentration limit, maxium contaminant level
MDM	Minimum discernible mark
MF	Membrane filter
MG	Geometric mean bias
MGD	Million gallons per day
MISR	Multi-angle Imaging SpectroRadiometer
MLMIS	Minnesota Land Management Information System
MLPs	Multilayer perceptrons
MMC	Modular Modeling Systems
MML	Module Markup Language
MMU	Minimum mapping unit
MODFLOW	Modular Flow or Modular Three-Dimensional Finite-Difference Groundwater Flow Model
MODIS	Moderate Resolution Imaging Spectroradiometer
MODM	Multimultiobjective decision making
MOS	Modular Optical Scanner
MPN	Most probable number
MRLCC	Multiresolution land characteristics consortium
MS	Management science

MSA	Metropolitan statistical area
MSL	Mean sea level
MSW	Municipal solid waste
MUIR	Map Unit Interpretations Record
NAD27	North American Datum 1927
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency (Japan)
NASIS	National Soil Information System
NAVSTAR	Navigation System by Timing and Ranging
NCDC	National Climatic Data Center
NCDCDS	National Committee for Digital Cartographic Data Standards
NDVI	Normalized difference vegetation index
NED	National Elevation Dataset
NGIA	National Geospatial Intelligence Agency
NGMC	National Geospatial Management Center
NGOs	Nongovernmental organizations
NGP	National Geospatial Program
NHD	National Hydrographic Dataset
NI	Non-irrigated
NLEAP	Nitrate Leaching and Economic Analysis Package
NMAS	National Map Accuracy Standards
NMSE	Normalized mean square error
NNRMS	National Natural Resource Management System (India)
NOAA	National Oceanic and Atmospheric Administration
NPS	nonpoint source
NRCS	National Resource Conservation Service
NSSDA	National Standard for Spatial Data Accuracy
NSSH	National Soil Survey Handbook
NTU	nephelometric turbidity unit
NWIS	National Water Information System
NWS	National Weather Service
O&I	Overlay and Index
OC	organic carbon
OCTS	Ocean Color and Temperature Scanner
ODE	ordinary differential equation
OGC	Open Geospatial Consortium
OK	ordinary kriging
OLS	ordinary least squares
OO	object-oriented
OODM	Object-oriented data model
OOP	Object-oriented programming
OR	Operations research
ORSTOM	Office de la recherche scientifique et technique outre-mer
OSF	Open-source software
PAR	Perimeter-area ratio
PCA	Principal component analysis
PCB	Polychlorinated biphenyl's
PCs	Principal components
PCSs	Permit compliance systems
PDA	Personal Digital Assistant
PDF	Probability density function
PDOP	Positional Dilution of Precision
PHABSIM	Physical (Fish) Habitat Simulation Model
PLASM	Prickett Lonnquist Aquifer Simulation Model
PLM	Patuxent Landscape Model
PLSS	Public Land Survey System
PNT	Position, navigation, and timing
POR	Period of record
PP	Point Profile
PRISM	Parameter-Elevation Regressions on Independent Slopes Model

此为试读,需要完整PDF请访问: www.ertongbook.com

PROMET	Process-oriented model for evapotranspiration
PRZM	Pesticide root zone model
PSI	Pathogen sensitivity index
PWS	public water system
QA/QC	Quality assurance and quality control
QGIS	Quantum GIS
R&O	Reclassification and overlay
RADARSAT-1	Radar Satellite
RBF	Radial basis function
RGB	Red-green-blue
RMSE	Root mean square error
ROI	Radius of influence
RPE	Raster Profile and Extension
RS	Remote Sensing
RTK	Real-Time Kinematic
RUSLE	Revised Universal Soil Loss Equation
SAC-SMA	Sacramento Soil Moisture Accounting
SCADA	Supervisory control and data acquisition
SCAN	Soil Climate Analysis Network
SCS	Soil Conservation Service
SCS-CN	Soil Conservation Survey Curve Number
SDM	Spatial data mining
SDTS	Spatial Data Transfer Standard
SHP	Southern High Plains
SI	Shape index
SMOS	Soil Moisture and Ocean Salinity Satellite
SOM	self-organizing maps
SPCS	State Plane Coordinate System
SPOT	Satellite Pour l'Observation de la Terre
SQL	Structured query language
SRTM	Shuttle Radar Topographic Mission
SSE	Sum of squared error
SSM/I	Special Sensor Microwave Imager
SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic Database
STC	Selecting Threshold Criteria
STORET	STOrage and RETrieval data warehouse
SVAT	Soil–vegetation–atmosphere transfer
SVM	Support vector machine
SWAT	Soil Water Assessment Tool
SWFWMD	Southwest Florida Water Management District
SYMAP	Synagraphic Mapping System
TAC	Texas Administrative Code
TauDEM	Terrain Analysis Using Digital Elevation Models
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TFN	Triangular fuzzy number
TGWV	True groundwater vulnerability
TIN	Triangular Irregular Network
TKN	Total Kjeldahl nitrogen
TM	Thematic Mapper
TMDL	Total Maximum Daily Load
TMS	Temporal map sets
TNP	Transportation Network Profile
TOPAZ	Topographic Parameterization
TOT	Time of travel
TPWD	Texas Parks and Wildlife Department
TQLs	Temporal query languages
TRMM	Tropical Rainfall Measuring Mission
TSS	Total suspended solids

TVP	Topological Vector Profile
TWDB	Texas Water Development Board
UAV	Unmanned automated vehicles
UK	Universal kriging
UML	Unified modeling language
USDA	US Department of Agriculture
USDA-NRCS	US Department of Agriculture National Resource Conservation Service
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VB Script	Visual Basic Script
VBA	Visual Basic for Applications
VC	Visual Complexity
VG	Geometric variance
VI	Vulnerability index
VIP	Very important points
VPF	Vector Product Format
WAAS	Wide Area Augmentation System
WAF	Waste application field
WAHS	Watershed Hydrology Simulation
WBD	Watershed boundary database
WBNM	Watershed Bounded Network Model
WGS84	World Geodetic System 1984
WHP	Well head protection
WHPA	Well head protection analysis
WHPR	Well head protection radius
WQ	Water quality
WQP	Water Quality Portal
WQSDB	Water Quality Standards Database
WRA	Water Resources Agency
WSC	Water supply corporation
WSN	Wireless sensor networks
WSRP	Water Supply Restoration Program
WWTP	Wastewater treatment plants
ZOI	Zone of influence

Contents

Preface xiii

About the Companion Website xv

List of Acronyms xvii

Part I GIS, Geocomputation, and GIS Data 1

1 Introduction 3

1.1 What is geocomputation? 3
1.2 Geocomputation and water resources science and engineering 4
1.3 GIS-enabled geocomputation in water resources science and engineering 5
1.4 Why should water resources engineers and scientists study GIS 5
1.5 Motivation and organization of this book 6
1.6 Concluding remarks 7
References 9

2 A Brief History of GIS and Its Use in Water Resources Engineering 11

2.1 Introduction 11
2.2 Geographic Information Systems (GIS) – software and hardware 11
2.3 Remote sensing and global positioning systems and development of GIS 12
2.4 History of GIS in water resources applications 13
2.5 Recent trends in GIS 19
2.6 Benefits of using GIS in water resources engineering and science 20
2.7 Challenges and limitations of GIS-based approach to water resources engineering 20
2.7.1 Limitation 1: incompatibilities between real-world and GIS modeled systems 20
2.7.2 Limitation 2: inability of GIS to effectively handle time dimension 21
2.7.3 Limitation 3: subjectivity arising from the availability of multiple geoprocessing tools 21
2.7.4 Limitation 4: ground-truthing and caution against extrapolation 21
2.7.5 Limitation 5: crisp representation of fuzzy geographic boundaries 21
2.7.6 Limitation 6: dynamic rescaling of maps and intrinsic resampling operations by GIS software 22
2.7.7 Limitation 7: inadequate or improper understanding of scale and resolution of the datasets 22
2.7.8 Limitation 8: limited support for handling of advanced mathematical algorithms 22
2.8 Concluding remarks 23
References 25

3 Hydrologic Systems and Spatial Datasets 27

3.1 Introduction 27
3.2 Hydrological processes in a watershed 27
3.3 Fundamental spatial datasets for water resources planning: management and modeling studies 28
3.3.1 Digital elevation models (DEMs) 28
3.4 Sources of data for developing digital elevation models 30
3.4.1 Accuracy issues surrounding digital elevation models 30
3.5 Sensitivity of hydrologic models to DEM resolution 31
3.5.1 Land use and land cover (LULC) 32
3.5.2 Sources of data for developing digital land use land cover maps 32
3.6 Accuracy issues surrounding land use land cover maps 32
3.6.1 Anderson classification and the standardization of LULC mapping 33
3.7 Sensitivity of hydrologic models to LULC resolution 34
3.7.1 LULC, impervious surface, and water quality 34
3.7.2 Soil datasets 36
3.8 Sources of data for developing soil maps 36
3.9 Accuracy issues surrounding soil mapping 37
3.10 Sensitivity of hydrologic models to soils resolution 38
3.11 Concluding remarks 43
References 44

4 Water-Related Geospatial Datasets 47

4.1 Introduction 47
4.2 River basin, watershed, and subwatershed delineations 47
4.3 Streamflow and river stage data 48
4.4 Groundwater level data 48
4.5 Climate datasets 48
4.6 Vegetation indices 49
4.7 Soil moisture mapping 49
4.7.1 Importance of soil moisture in water resources applications 49
4.7.2 Methods for obtaining soil moisture data 50
4.7.3 Remote sensing methods for soil moisture assessments 50
4.7.4 Role of GIS in soil moisture modeling and mapping 51
4.8 Water quality datasets 51
4.9 Monitoring strategies and needs 51
4.10 Sampling techniques and recent advancements in sensing technologies 52
4.11 Concluding remarks 53
References 53

5 Data Sources and Models 55

5.1 Digital data warehouses and repositories 55
5.2 Software for GIS and geocomputations 55
5.3 Software and data models for water resources applications 59
5.4 Concluding remarks 60
References 60

Part II Foundations of GIS 61

6 Data Models for GIS 63

6.1 Introduction 63
6.2 Data types, data entry, and data models 63
6.2.1 Discrete and continuous data 63
6.3 Categorization of spatial datasets 65
6.3.1 Raster and vector data structures 65
6.3.2 Content-based data classification 65

6.3.3 Data classification based on measurement levels 66
6.3.4 Primary and derived datasets 69
6.3.5 Data entry for GIS 69
6.3.6 GIS data models 70
6.4 Database structure, storage, and organization 71
6.4.1 What is a relational data structure? 71
6.4.2 Attribute data and tables 72
6.4.3 Geodatabase 73
6.4.4 Object-oriented database 75
6.5 Data storage and encoding 75
6.6 Data conversion 76
6.7 Concluding remarks 78
References 80

7 Global Positioning Systems (GPS) and Remote Sensing 81

7.1 Introduction 81
7.2 The global positioning system (GPS) 81
7.3 Use of GPS in water resources engineering studies 82
7.4 Workflow for GPS data collection 83
7.4.1 12 Steps to effective GPS data collection and compilation 83
7.5 Aerial and satellite remote sensing and imagery 83
7.5.1 Low-resolution imagery 84
7.5.2 Medium-resolution imagery 84
7.5.3 High-resolution imagery 84
7.6 Data and cost of acquiring remotely sensed data 84
7.7 Principles of remote sensing 85
7.8 Remote sensing applications in water resources engineering and science 88
7.9 Bringing remote sensing data into GIS 91
7.9.1 Twelve steps for integration of remotely sensed data into GIS 93
7.10 Concluding remarks 94
References 95

8 Data Quality, Errors, and Uncertainty 97

8.1 Introduction 97
8.2 Map projection, datum, and coordinate systems 97
8.3 Projections in GIS software 101
8.4 Errors, data quality, standards, and documentation 102
8.5 Error and uncertainty 106
8.6 Role of resolution and scale on data quality 107
8.7 Role of metadata in GIS analysis 109
8.8 Concluding remarks 109
References 109

9 GIS Analysis: Fundamentals of Spatial Query 111

9.1 Introduction to spatial analysis 111
9.2 Querying operations in GIS 116
9.2.1 Spatial query 116
9.3 Structured query language (SQL) 119
9.4 Raster data query by cell value 122
9.5 Spatial join and relate 125
9.6 Concluding remarks 128
References 128

10 Topics in Vector Analysis 129

10.1 Basics of geoprocessing (buffer, dissolve, clipping, erase, and overlay) 129
10.1.1 Buffer 129
10.1.2 Dissolve, clip, and erase 132
10.1.3 Overlay 132
10.2 Topology and geometric computations (various measurements) 137
10.2.1 Length and distance measurements 139
10.2.2 Area and perimeter-to-area ratio (PAR) calculations 140
10.3 Proximity and network analysis 143
10.3.1 Proximity 144
10.3.2 Network analysis 144
10.4 Concluding remarks 145
References 147

11 Topics in Raster Analysis 149

11.1 Topics in raster analysis 149
11.2 Local operations 149
11.2.1 Local operation with a single raster 151
11.2.2 Local operation with multiple rasters 151
11.2.3 Map algebra for geocomputation in water resources 153
11.3 Reclassification 155
11.4 Zonal operations 157
11.4.1 Identification of regions and reclassification 160
11.4.2 Category-wide overlay 161
11.5 Calculation of area, perimeter, and shape 163
11.6 Statistical operations 164
11.7 Neighborhood operations 165
11.7.1 Spatial aggregation analysis 165
11.7.2 Filtering 166
11.7.3 Computation of slope and aspect 167
11.7.4 Resampling 167
11.8 Determination of distance, proximity, and connectivity in raster 167
11.9 Physical distance and cost distance analysis 169
11.9.1 Cost surface analysis 172
11.9.2 Allocation and direction analysis 172
11.9.3 Path analysis 173
11.10 Buffer analysis in raster 174
11.11 Viewshed analysis 175
11.12 Raster data management (mask, spatial clip, and mosaic) 178
11.13 Concluding remarks 179
References 181

12 Terrain Analysis and Watershed Delineation 183

12.1 Introduction 183
12.1.1 Contouring 184
12.1.2 Hill shading and insolation 185
12.1.3 Perspective view 186
12.1.4 Slope and aspect 186
12.1.5 Surface curvature 191
12.2 Topics in watershed characterization and analysis 191
12.2.1 Watershed delineation 192
12.2.2 Critical considerations during watershed delineation 198
12.3 Concluding remarks 200
References 200

Part III Foundations of Modeling 203

13 Introduction to Water Resources Modeling 205

13.1 Mathematical modeling in water resources engineering and science 205
13.2 Overview of mathematical modeling in water resources engineering and science 206
13.3 Conceptual modeling: phenomena, processes, and parameters of a system 206
13.4 Common approaches used to develop mathematical models in water resources engineering 206
13.4.1 Data-driven models 207
13.4.2 Physics-based models 208
13.4.3 Expert-driven or stakeholder-driven models 208
13.5 Coupling mathematical models with GIS 209
13.5.1 Loose coupling of GIS and mathematical models 209
13.5.2 Tight coupling of GIS and mathematical models 209
13.5.3 What type of coupling to pursue? 210
13.6 Concluding remarks 210
References 211

14 Water Budgets and Conceptual Models 213

14.1 Flow modeling in a homogeneous system (boxed or lumped model) 213

14.2 Flow modeling in heterogeneous systems (control volume approach) 215
14.3 Conceptual model: soil conservation survey curve number method 217
14.4 Fully coupled watershed-scale water balance model: soil water assessment tool (SWAT) 218
14.5 Concluding remarks 219
References 220

15 Statistical and Geostatistical Modeling 221

15.1 Introduction 221
15.2 Ordinary least squares (OLS) linear regression 221
15.3 Logistic regression 222
15.4 Data reduction and classification techniques 223
15.5 Topics in spatial interpolation and sampling 223
15.5.1 Local area methods 224
15.5.2 Spline interpolation method 224
15.5.3 Thiessen polygons 224
15.5.4 Density estimation 225
15.5.5 Inverse distance weighted (IDW) 226
15.5.6 Moving average 226
15.5.7 Global area or whole area interpolation schemes 227
15.5.8 Trend surface analysis 227
15.6 Geostatistical Methods 227
15.6.1 Spatial autocorrelation 227
15.6.2 Variogram and semivariogram modeling 228
15.7 Kriging 230
15.8 Critical issues in interpolation 231
15.9 Concluding remarks 232
References 234

16 Decision Analytic and Information Theoretic Models 235

16.1 Introduction 235
16.2 Decision analytic models 235
16.2.1 Multiattribute decision-making models 235
16.2.2 Multiobjective decision-making models 238
16.3 Information theoretic approaches 238
16.3.1 Artificial neural networks (ANNs) 239
16.3.2 Support vector machines (SVMs) 239
16.3.3 Rule-based expert systems 240
16.3.4 Fuzzy rule-based inference systems 241
16.3.5 Neuro-fuzzy systems 243
16.4 Spatial data mining (SDM) for knowledge discovery in a database 245
16.5 The trend of temporal data modeling in GIS 245
16.6 Concluding remarks 246
References 246

17 Considerations for GIS and Model Integration 249

17.1 Introduction 249
17.2 An overview of practical considerations in adopting and integrating GIS into water resources projects 250
17.3 Theoretical considerations related to GIS and water resources model integration 251
17.3.1 Space and time scales of the problems and target outcomes 251
17.3.2 Data interchangeability and operability 253
17.3.3 Selection of the appropriate platform, models, and datasets 253
17.3.4 Model calibration and evaluation issues 255
17.3.5 Error and uncertainty analysis 255
17.4 Concluding remarks 256
References 257

18 Useful Geoprocessing Tasks While Carrying Out Water Resources Modeling 259

18.1 Introduction 259
18.2 Getting all data into a common projection 259
18.3 Adding point (*X*, *Y*) data and calculating their projected coordinates 260
18.4 Image registration and rectification 264
18.5 Editing tools to transfer information to vectors 266
18.6 GIS for cartography and visualization 270
18.7 Concluding remarks 271
References 271

19 Automating Geoprocessing Tasks in GIS 273

19.1 Introduction 273
19.2 Object-oriented programming paradigm 273
19.3 Vectorized (array) geoprocessing 274
19.4 Making nongeographic attribute calculations 274
19.4.1 Field calculator for vector attribute manipulation 274
19.4.2 Raster calculator for continuous data 278
19.5 Using ModelBuilder to automate geoprocessing tasks 279
19.6 Using Python scripting for geoprocessing 287
19.7 Introduction to some useful Python constructs 288
19.7.1 Basic arithmetic and programming logic syntax 288
19.7.2 Defining functions in Python 288
19.7.3 Python classes 288
19.7.4 Python modules and site-packages 289
19.8 ArcPy geoprocessing modules and site-package 289
19.9 Learning Python and scripting with ArcGIS 289
19.10 Concluding remarks 290
References 291

Part IV Illustrative Case Studies 293

A Preamble to Case Studies 295

20 Watershed Delineation 297

20.1 Introduction 297
20.2 Background 297
20.3 Methods 298
20.3.1 Generalized methods 298
20.3.2 Application 298
20.3.3 Application of ArcGIS Spatial Analyst tools 298
20.3.4 Application of ArcHydro for drainage analysis using digital terrain data 303
20.4 Concluding remarks 311
References 311

21 Loosely Coupled Hydrologic Model 313

21.1 Introduction 313
21.2 Study area 313
21.3 Methods 314
21.3.1 Image processing 315
21.3.2 ET/EV data 317
21.3.3 Accuracy assessment 317
21.3.4 Water budget spreadsheet model 317
21.4 Results and discussions 318
21.4.1 Image classification results 318
21.4.2 Water budget calculation 319
21.5 Conclusions 323
Acknowledgment 324
References 324

22 Watershed Characterization 325

22.1 Introduction 325
22.2 Background 325
22.3 Approach 326
22.3.1 Analysis of watershed characteristics and reclassification 327
22.3.2 Integrated evaluation of watershed runoff potential 330
22.4 Summary and conclusions 332
References 345

23 Tightly Coupled Models with GIS for Watershed Impact Assessment 347

23.1 Introduction 347
23.1.1 Land use and soil influences on runoff and the curve number (CN) 347
23.2 Methods 350
23.2.1 Study area 350
23.2.2 Data processing 350
23.2.3 Data layers 351
23.3 Results and discussion 353
23.4 Summary and conclusions 357
References 357

24 GIS for Land Use Impact Assessment 359

24.1 Introduction 359
24.2 Description of study area and datasets 360
24.3 Results and discussion 370
24.4 Conclusions 386
References 387

25 TMDL Curve Number 389

25.1 Introduction 389
25.2 Formulation of competing models 389
25.3 Use of Geographic Information System to obtain parameters for use in the NRCS method 390
25.3.1 Nonpoint source loading determination 391
25.4 Risk associated with different formulations 392
25.5 Summary and conclusions 394
References 395

26 Tight Coupling MCDM Models in GIS 397

26.1 Introduction 397
26.2 Using GIS for groundwater vulnerability assessment 398
26.3 Application of DRASTIC methodology in South Texas 398
26.4 Study area 398
26.5 Compiling the database for the DRASTIC index 398
26.6 Development of DRASTIC vulnerability index 399
26.6.1 Depth to groundwater 400
26.6.2 Recharge 401
26.6.3 Aquifer media 401
26.6.4 Soil media 401
26.6.5 Topography 402
26.6.6 Impact of vadose zone 402
26.6.7 Hydraulic conductivity 403
26.7 DRASTIC index 403
26.8 Summary 404
References 404

27 Advanced GIS MCDM Model Coupling for Assessing Human Health Risks 405

27.1 Introduction 405
27.2 Background information 406
27.2.1 Groundwater vulnerability parameters 406
27.2.2 Pathogen transport parameters 406
27.2.3 Pathogen survival parameters 407
27.3 Methods 407
27.3.1 Study area 407
27.3.2 Conceptual framework 407
27.3.3 Data layers 408
27.4 Results and discussion 412
27.5 Conclusions 419
References 419

28 Embedded Coupling with JAVA 421

28.1 Introduction 421
28.2 Previous work 422
28.3 Mathematical background 422
28.4 Data formats of input files 423
28.5 AFC structure and usage 423
28.6 Illustrative example 424
References 426

29 GIS-Enabled Physics-Based Contaminant Transport Models for MCDM 427

29.1 Introduction 427
29.2 Methodology 428
29.2.1 Conceptual model 428
29.2.2 Mass-balance expressions 429
29.2.3 Solutions of the steady-state mass-balance equation 430
29.2.4 Model parameterization 431
29.3 Results and discussion 433
29.3.1 Sensitivity analysis 435
29.4 Summary and conclusions 437
References 437

30 Coupling of Statistical Methods with GIS for Groundwater Vulnerability Assessment 439

30.1 Introduction 439
30.1.1 Logistic regression 439
30.1.2 Akaike's information criterion (AIC) 440
30.2 Methodology 440
30.2.1 Application of logistic regression (LR) to DRASTIC vulnerability model 440
30.2.2 Implementation in GIS 440
30.3 Results and discussion 440
30.3.1 Implementation in GIS 441
30.4 Summary and conclusions 444
References 444

31 Coupling of Fuzzy Logic-Based Method with GIS for Groundwater Vulnerability Assessment 447

31.1 Introduction 447
31.2 Methodology 448
31.2.1 Fuzzy sets and fuzzy numbers 448
31.2.2 Fuzzy arithmetic 449
31.2.3 Elementary fuzzy arithmetic for triangular fuzzy sets 449
31.2.4 Approximate operations on triangular fuzzy sets 449
31.2.5 Fuzzy aquifer vulnerability characterization 450
31.2.6 Specification of weights 450
31.2.7 Specification of ratings 450
31.2.8 Defuzzification procedures 452
31.2.9 Implementation 453
31.3 Results and discussion 453
31.3.1 Incorporation of fuzziness in decision-makers' weights and ratings 453
31.3.2 Comparison of exact and approximate fuzzy arithmetic for aquifer vulnerability estimation when ratings and weights are fuzzy 453
31.4 Summary and conclusions 457
References 457

32 Tight Coupling of Artificial Neural Network (ANN) and GIS 461

32.1 Introduction 461
32.1.1 The concept of artificial neural network (ANN) 461
32.2 Methodology 463
32.2.1 Data development 463
32.2.2 Application of feedforward neural network (FFNN) to DRASTIC groundwater vulnerability assessment model 463
32.2.3 Application of radial basis function (RBF) neural network to DRASTIC groundwater vulnerability assessment model 464

此为试读,需要完整PDF请访问: www.ertongbook.com