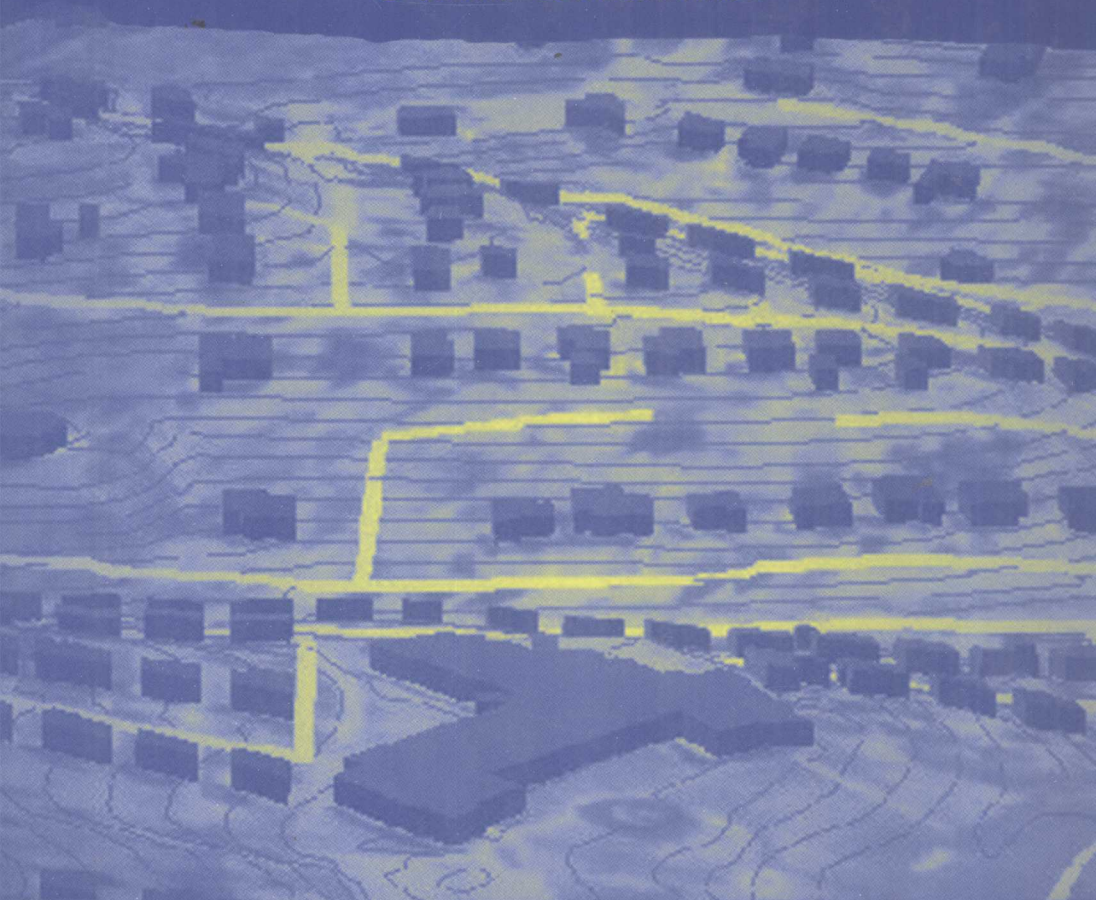


032 22595 194184

GIS Applications for Water, Wastewater, and Stormwater Systems

U.M. Shamsi



A CRC PRESS BOOK

GIS Applications for Water, Wastewater, and Stormwater Systems

U.M. Shamsi



Taylor & Francis
Taylor & Francis Group

Boca Raton London New York Singapore

A CRC title, part of the Taylor & Francis imprint, a member of the
Taylor & Francis Group, the academic division of T&F Informa plc.

2487300

Library of Congress Cataloging-in-Publication Data

Shamsi, U. M. (Uzair M.)

GIS applications for water, wastewater, and stormwater systems / U.M. Shamsi.
p. cm.

Includes bibliographical references and index.

ISBN 0-8493-2097-6 (alk. paper)

1. Water—Distribution. 2. Sewage disposal. 3. Runoff—Management. 4. Geographic information systems. I. Title.

TD482.S53 2005

628.1--dc22

2004057108

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the author and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage or retrieval system, without prior permission in writing from the publisher.

The consent of CRC Press does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from CRC Press for such copying.

Direct all inquiries to CRC Press, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

Visit the CRC Press Web site at www.crcpress.com

© 2005 by CRC Press

No claim to original U.S. Government works

International Standard Book Number 0-8493-2097-6

Library of Congress Card Number 2004057108

Printed in the United States of America 1 2 3 4 5 6 7 8 9 0

Printed on acid-free paper

Dedication

*Dedicated to my beloved wife, Roshi, and my children,
Maria, Adam, and Harris*

Preface

To fully appreciate the benefits of GIS applications consider the following hypothetical scenario. On March 10, 2004, following a heavy storm event, a sewer customer calls the Sewer Authority of the City of Cleanwater to report minor basement flooding without any property damage. An Authority operator immediately starts the GIS and enters the customer address. GIS zooms to the resident property and shows all the sewers and manholes in the area. The operator queries the inspection data for a sewer segment adjacent to the customer property and finds that a mini movie of the closed-circuit television (CCTV) inspection dated July 10, 1998, is available. The operator plays the movie and sees light root growth in the segment. A query of the maintenance history for that segment indicates that it has not been cleaned since April 5, 1997. This information indicates that the roots were never cleaned and have probably grown to “heavy” status. The operator highlights the sewer segment, launches the work order module, and completes a work order form for CCTV inspection and root removal, if necessary. The export button saves the work order form and a map of the property and adjacent sewers in a PDF file. The operator immediately sends the PDF file by e-mail to the Authority’s sewer cleaning contractor. The entire session from the time the customer called the Authority office took about 30 min. The operator does not forget to call the customer to tell him that a work order has been issued to study the problem. This book presents the methods and examples required to develop applications such as this.

The days of the slide rule are long gone. Word processors are no longer considered cutting-edge technology. We are living in an information age that requires us to be more than visionaries who can sketch an efficient infrastructure plan. This tech-heavy society expects us to be excellent communicators who can keep all the stakeholders — the public, the regulators, or the clients — “informed.” New information and decision support systems have been developed to help us to be good communicators. GIS is one such tool that helps us to communicate geographic or spatial information. The real strength of GIS is its ability to integrate information. GIS helps decision makers by pulling together crucial bits and pieces of information as a whole and showing them the “big picture.” In the past 10 years, the number of GIS users has increased substantially. Many of us are using GIS applications on the Internet and on wireless devices without even knowing that we are using a GIS. Experts believe that in the near future, most water, wastewater, and stormwater system professionals will be using the GIS in the same way they are now using a word processor or spreadsheet. Except for the computer itself, no technology has so revolutionized the water industry. The time has come for all the professionals involved in the planning, design, construction, and operation of water, wastewater, and stormwater systems to enter one of the most promising and exciting technologies of the millennium in their profession — GIS applications.

According to some estimates, more than 80% of all the information used by water and sewer utilities is geographically referenced.

This book was inspired from a continuing education course that the author has been teaching since 1998 for the American Society of Civil Engineers (ASCE). Entitled “GIS Applications in Water, Wastewater and Stormwater Systems,” the seminar course has been attended by hundreds of water, wastewater, and stormwater professionals in major cities of the United States. Many models, software, examples, and case studies described in the book (especially those from Pennsylvania) are based on the GIS projects worked on or managed by the author himself.

This is my second GIS book for water, wastewater, and stormwater systems. The first book, *GIS Tools for Water, Wastewater, and Stormwater Systems*, published by American Society of Civil Engineers (ASCE) Press in 2002, was a huge success. The first printing was sold out, and the book achieved ASCE Press’s best-seller status within months of publication. Whereas the first book focused on GIS basics and software and data tools to develop GIS applications, this second book focuses on the practical applications of those tools. Despite the similarity of the titles, both books cover different topics and can be read independent of each other.

STYLE OF THE BOOK

This book has been written using the recommendations of the Accreditation Board for Engineering and Technology (ABET) of the U.S. and the American Society of Civil Engineers’ (ASCE) Excellence in Civil Engineering Education (ExCEED) program. Both of these organizations recommend performance- (or outcome-) based learning in which the learning objectives of each lecture (or chapter) are clearly stated up front, and the learning is measured in terms of achieving these learning objectives. Each chapter of this book accordingly starts with learning objectives for that chapter and ends with a chapter summary and questions. Most technical books are written using the natural human teaching style called *deductive*, in which principles are presented before the applications. In this book, an attempt has been made to organize the material in the natural human learning style called *inductive*, in which examples are presented before the principles. For example, in most chapters, case studies are presented before the procedures are explained. The book has numerous maps and illustrations that should cater well to the learning styles of “visual learners” — GIS, after all is regarded as a visual language.

The primary learning objective of this book is to document GIS applications for water, wastewater, and stormwater systems. This book will show you how to use GIS to make tasks easier to do and increase productivity, and hence, save time and money in your business.

ORGANIZATION OF THE BOOK

There are 17 chapters in this book, organized as follows:

- Chapter 1, GIS Applications: Describes why GIS applications are important and how they are created

- Chapter 2, Needs Analysis: Explains how to avoid potential pitfalls of GIS implementation by starting with a needs analysis study

The next five chapters describe four GIS-related technologies that are very beneficial in developing GIS applications:

- Chapter 3, Remote Sensing Applications: Shows how to use satellite imagery in GIS applications
- Chapter 4, DEM Applications: Describes the methods of incorporating digital elevation model (DEM) data
- Chapter 5, GPS Applications: Discusses how to benefit from global positioning system (GPS) technology
- Chapter 6, Internet Applications: Explains the applications of Internet technology in serving GIS maps on the Internet
- Chapter 7, Mobile GIS: Provides information on using GIS in the field for inspection and maintenance work

The GIS applications that are of particular importance to water industry professionals are: Mapping, Monitoring, Modeling, and Maintenance. These four *M*s define some of the most important activities for efficient management of water, wastewater, and stormwater systems, and are referred to as the “4M applications” in this book. The next ten chapters focus on these four *M*s.

- Chapter 8, Mapping: Describes how to create the first *M* of the 4M applications
- Chapter 9, Mapping Applications: Describes examples of the first *M* of the 4M applications
- Chapter 10, Monitoring Applications: Describes the applications of the second *M* of the 4M applications
- Chapter 11, Modeling Applications: Describes the applications of the third *M* of the 4M applications
- Chapter 12, Water Models: Describes examples of the third *M* of the 4M applications for modeling water distribution systems
- Chapter 13, Sewer Models: Describes examples of the third *M* of the 4M applications for modeling sewage collection systems
- Chapter 14, AM/FM/GIS Applications: Describes automated mapping/facilities management/geographic information system (AM/FM/GIS) software tools for implementing the fourth *M* of the 4M applications
- Chapter 15, Maintenance Applications: Describes the applications of the fourth *M* of the 4M applications
- Chapter 16, Security Planning and Vulnerability Assessment: Discusses GIS applications for protecting water and wastewater systems against potential terrorist attacks
- Chapter 17, Applications Sampler: Presents a collection of recent case studies from around the world

Acknowledgments

Case studies presented in Chapter 17, Applications Sampler, were written specially for publication in this book by 18 GIS and water industry experts from 6 countries (Belgium, Bulgaria, Czech Republic, Denmark, Spain and the United States) in response to my call for case studies distributed to various Internet discussion forums. I thank these case study authors for their contributions to this book:

- Bart Reynaert, Rene Horemans, and Patrick Vercruyssen of Pidpa, Belgium
- Carl W. Chen and Curtis Loeb of Systech Engineering, Inc., San Ramon, California
- Dean Trammel, Tucson Water, Tucson, Arizona
- Ed Bradford, Roger Watson, Eric Mann, Jenny Konwinski of Metropolitan Sewerage District of Buncombe County, North Carolina
- Eric Fontenot of DHI, Inc., Hørsholm, Denmark
- Milan Suchanek and Tomas Metelka of Sofiyska Voda A.D., Sofia, Bulgaria
- Peter Ingeduld, Zdenek Svitak, and Josef Drbohlav of Pražská vodohospodářská společnost a.s. (Prague stockholding company), Prague, Czech Republic
- Hugo Bartolin and Fernando Martinez of Polytechnic University of Valencia, Spain

I also thank the following organizations and companies for providing information for this book: American Society of Civil Engineers, American Water Works Association, Azteca Systems, *CE Magazine*, CH2M Hill, Chester Engineers, Computational Hydraulics International, Danish Hydraulic Institute (DHI), Environmental Systems Research Institute, *Geospatial Solutions Magazine*, *GEOWorld Magazine*, Haestad Methods, Hansen Information Technology, *Journal of the American Water Resources Association*, *Journal of the American Water Works Association*, MWH Soft, *Professional Surveyor Magazine*, USFilter, *Water Environment Federation*, and *Water Environment & Technology Magazine*. Some information presented in this book is based on my collection of papers and articles published in peer-reviewed journals, trade magazines, conference proceedings, and the Internet. The authors and organizations of these publications are too numerous to be thanked individually, so I thank them all collectively without mentioning their names. Their names are, of course, included in the Reference section.

Finally, I would like to thank you for buying the book. I hope you will find the book useful in maximizing the use of GIS in your organization to make things easier to do, increase productivity, and save time and money.

About the Author

Uzair (Sam) M. Shamsi, Ph.D., P.E., DEE is director of the GIS and Information Management Technology division of Chester Engineers, Pittsburgh, Pennsylvania, and an adjunct assistant professor at the University of Pittsburgh, where he teaches GIS and hydrology courses. His areas of specialization include GIS applications and hydrologic and hydraulic (H&H) modeling. He has been continuing education instructor for the American Society of Civil Engineers (ASCE) and an Environmental Systems Research Institute (ESRI)-authorized ArcView® GIS instructor since 1998. He has taught GIS courses to more than 500



professionals throughout the United States, including a course on “GIS Applications in Water, Wastewater, and Stormwater Systems” for ASCE. Sam earned his Ph.D. in civil engineering from the University of Pittsburgh in 1988. He has 20 years of GIS and water and wastewater engineering experience in teaching, research, and consulting. His accomplishments include more than 120 projects and over 100 lectures and publications, mostly in GIS applications. His previous book, *GIS Tools for Water, Wastewater, and Stormwater Systems*, was an ASCE Press best seller. He is the recipient of the ASCE’s Excellence in Civil Engineering Education (EXCEED) training and is a licensed professional engineer in Pennsylvania, Ohio, and West Virginia. In addition to ASCE, he is a member of the American Water Resources Association, the Water Environment Foundation, and the American Water Works Association.

E-mail: ushamsi@GISApplications.com

Web site: www.GISApplications.com

GIS is an instrument for implementing geographic thinking

Jack Dangermond (1998)

Iron rusts from disuse; water loses its purity from stagnation and in cold weather becomes frozen; even so does inaction sap the vigors of the mind.

Leonardo da Vinci (1452–1519)

Life is like a sewer...what you get out of it depends on what you put into it.

Tom Lehrer (1928–)

Times of general calamity and confusion create great minds. The purest ore is produced from the hottest furnace, and the brightest thunderbolt is elicited from the darkest storms.

Charles Caleb Colton (1780–1832)

Contents

Chapter 1	GIS Applications	
Learning Objective		2
Major Topics		2
List of Chapter Acronyms		2
Introduction.....		2
What Are GIS Applications?		3
History of GIS Applications		4
4M Applications		6
Advantages and Disadvantages of GIS Applications		6
Advantages		7
GIS Applications Save Time and Money.....		7
GIS Applications Are Critical to Sustaining GIS Departments.....		7
GIS Applications Provide the Power of Integration.....		8
GIS Applications Offer a Decision Support Framework.....		8
GIS Applications Provide Effective Communication Tools.....		9
GIS Applications Are Numerous.....		9
Disadvantages.....		12
Success Stories		13
San Diego.....		13
Boston.....		13
Cincinnati		13
Knoxville.....		14
Dover.....		14
Charlotte.....		14
Albany County		14
GIS Applications Around the World.....		15
Evolving GIS Applications and Trends.....		15
Future Applications and Trends		16
GIS Application Development Procedure		19
Application Programming		20
GIS-Based Approach.....		20
GIS Customization.....		20
Scripting		20
Extensions		21
External Programs.....		23
Application-Based Approach		24
Useful Web Sites		24
Chapter Summary		24
Chapter Questions.....		25
Chapter 2	Needs Analysis	
Learning Objective		28
Major Topics.....		28

List of Chapter Acronyms	28
Ocean County's Strategic Plan	28
Introduction	28
Needs Analysis Steps	29
Step 1. Stakeholder Identification	30
Step 2. Stakeholder Communication	30
Introductory Seminar	31
Work Sessions and Focus Groups	31
Interviews	31
Step 3. Resource Inventory	32
Step 4. Need Priorities	33
Step 5. System Design	33
Data Conversion (Mapping)	33
Database	34
Software Selection	36
Hardware Selection	37
User Interface	38
Step 6. Pilot Project	40
Step 7. Implementation Plan	41
Step 8. Final Presentation	43
Needs Analysis Examples	43
Pittsburgh, Pennsylvania	43
Borough of Ramsey, New Jersey	44
The City of Bloomington, Indiana	45
San Mateo County, California	45
Chapter Summary	45
Chapter Questions	46

Chapter 3 Remote Sensing Applications

Learning Objective	48
Major Topics	48
List of Chapter Acronyms	48
Albany County's Remote Sensing Application	48
Introduction	49
Remote Sensing Applications	51
Remote Sensing Satellites	52
Spatial Resolution	53
Low-Resolution Satellite Data	53
Medium-Resolution Satellite Data	54
High-Resolution Satellite Data	56
High-Resolution Satellites	56
High-Resolution Imagery Applications	58
Data Sources	59
Digital Orthophotos	59
USGS Digital Orthophotos	60
Case Study: Draping DOQQ Imagery on DEM Data	62

Examples of Remote Sensing Applications	62
LULC Classification	62
Soil Moisture Mapping	65
Estimating Meteorological Data	66
Geographic Imaging and Image Processing Software	66
ERDAS Software Products	66
ERDAS Software Application Example	68
ArcView Image Analysis Extension	69
MrSID	69
PCI Geomatics	70
Blue Marble Geographics	71
Future Directions	72
Useful Web Sites	73
Chapter Summary	73
Chapter Questions	73

Chapter 4 DEM Applications

Learning Objective	76
Major Topics	76
List of Chapter Acronyms	76
Hydrologic Modeling of the Buffalo Bayou Using GIS and DEM Data	76
DEM Basics	77
DEM Applications	79
Three-Dimensional (3D) Visualization	79
DEM Resolution and Accuracy	80
USGS DEMs	81
USGS DEM Formats	82
National Elevation Dataset (NED)	83
DEM Data Availability	83
DEM Data Creation from Remote Sensing	84
Image Processing Method	84
Data Collection Method	84
LIDAR	85
IFSAR	85
DEM Analysis	86
Cell Threshold for Defining Streams	86
The D-8 Model	86
DEM Sinks	87
Stream Burning	88
DEM Aggregation	88
Slope Calculations	88
Software Tools	88
Spatial Analyst and Hydro Extension	90
ARC GRID Extension	93
IDRISI	94
TOPAZ	95

Case Studies and Examples.....	95
Watershed Delineation	95
Sewershed Delineation.....	101
Water Distribution System Modeling	103
WaterCAD Example.....	104
Useful Web Sites	105
Chapter Summary	105
Chapter Questions.....	106

Chapter 5 GPS Applications

Learning Objective	108
Major Topics	108
List of Chapter Acronyms	108
Stream Mapping in Iowa	108
GPS Basics	109
GPS Applications in the Water Industry	110
Surveying.....	111
Fleet Management.....	111
GPS Applications in GIS.....	111
GPS Survey Steps.....	112
GPS Equipment	113
Recreational GPS Equipment	113
Basic GPS Equipment.....	114
Advanced GPS Equipment	115
Survey Grade GPS Equipment.....	116
Useful Web Sites	117
Chapter Summary	117
Chapter Questions.....	118

Chapter 6 Internet Applications

Learning Objective	120
Major Topics	120
List of Chapter Acronyms	120
Dublin's Web Map.....	120
Internet GIS	122
Internet Security	123
Internet GIS Software.....	124
Internet GIS Applications.....	124
Data Integration.....	124
Project Management	124
3D Visualization Applications	126
Case Studies.....	126
Tacoma's Intranet and Mobile GIS	126
Montana's Watershed Data Information Management System.....	127
Useful Web Sites	128

Chapter Summary	128
Chapter Questions.....	128

Chapter 7 Mobile GIS

Learning Objective	130
Major Topics	130
List of Chapter Acronyms	130
Mobile GIS Basics.....	130
Mobile GIS Applications.....	131
Wireless Internet Technology	133
GPS Integration	133
Useful Web Sites	134
Chapter Summary	135
Chapter Questions.....	135

Chapter 8 Mapping

Learning Objective	138
Major Topics	138
List of Chapter Acronyms	138
Los Angeles County's Sewer Mapping Program.....	138
Mapping Basics	139
Map Types	139
Topology.....	139
Map Projections and Coordinate Systems.....	140
Map Scale.....	140
Data Quality	140
Data Errors	141
Map Accuracy	141
Map Types.....	142
Base Map.....	142
Digital Orthophotos.....	143
Planimetric Maps	143
Small-Scale Maps	144
Advantages of GIS Maps	145
GIS Mapping Steps	147
Needs Analysis.....	147
Data Collection	148
Data Conversion.....	148
Capturing Attributes	148
Capturing Graphics	149
Digitization.....	149
Scanning.....	150
Data Conversion Software.....	150
Data Processing.....	153
Data Preparation.....	153
Topological Structuring.....	153

Data Management	154
Quality Control	155
Map Production.....	155
Case Studies.....	156
Borough of Ramsey, New Jersey.....	156
City of Lake Elsinore, California	158
Allegheny County, Pennsylvania	159
Useful Web Sites	159
Chapter Summary	160
Chapter Questions.....	160

Chapter 9 Mapping Applications

Learning Objective	162
Major Topics	162
List of Chapter Acronyms	162
Customer Service Application in Gurnee	162
Common Mapping Functions.....	164
Thematic Mapping	164
Spatial Analysis.....	164
Buffers	164
Hyperlinks	167
Water System Mapping Applications.....	167
MWRA Water System Mapping Project	167
Service Shutoff Application.....	167
Generating Meter-Reading Routes	169
Map Maintenance Application.....	169
Wastewater System Mapping Applications.....	169
Public Participation with 3D GIS	169
Mapping the Service Laterals.....	170
Stormwater System Mapping Applications.....	173
Stormwater Permits	173
Chapter Summary	175
Chapter Questions.....	175

Chapter 10 Monitoring Applications

Learning Objective	178
Major Topics	178
List of Chapter Acronyms	178
Monitoring Real Time Rainfall and Stream-Flow Data in Aurora.....	178
Monitoring Basics.....	179
Remotely Sensed Rainfall Data	179
Satellite Rainfall Data.....	180
Radar Rainfall Data	181
NEXRAD Rainfall Data	181
NEXRAD Level III Data.....	181
Estimating Rainfall Using GIS	183

Radar Rainfall Application: Virtual Rain-Gauge Case Study	184
Flow-Monitoring Applications	187
SCADA Integration	187
NPDES-Permit Reporting Applications	188
Monitoring via Internet	189
Monitoring the Infrastructure	190
Useful Web Sites	190
Chapter Summary	191
Chapter Questions.....	191

Chapter 11 Modeling Applications

Learning Objectives.....	194
Major Topics	194
List of Chapter Acronyms	194
Temporal-Spatial Modeling in Westchester County	194
H&H Modeling.....	195
Application Methods	196
Interchange Method.....	197
Subbasin Parameter Estimation	198
Runoff Curve Number Estimation.....	199
Water Quality Modeling Data Estimation	200
Demographic Data Estimation.....	202
Land-Use Data Estimation.....	204
Interface Method.....	205
HEC-GEO Interface	207
HEC-GeoHMS	207
HEC-GeoRAS	207
Watershed Modeling System	208
GISHydro Modules.....	208
GISHydro Prepro	209
GISHydro Runoff.....	210
ArcInfo Interface with HEC Programs.....	210
Intermediate Data Management Programs	211
Interface Method Case Study	212
Integration Method	212
EPA's BASINS Program	213
BASINS Examples.....	217
MIKE BASIN.....	218
Geo-STORM Integration	219
ARC/HEC-2 Integration	219
Integration Method Case Study	220
Which Linkage Method to Use?	221
Useful Web Sites	222
Chapter Summary	222
Chapter Questions.....	223