#### TECHNIQUES OF WATER-RESOURCES INVESTIGATIONS OF THE U.S. GEOLOGICAL SURVEY

The USGS publishes a series of manuals, the Techniques of Water-Resources Investigations, describing procedures for planning and conducting specialized work in water-resources investigations. The material is grouped under major subject headings called books and is further divided into sections and chapters. For example, section A of book 3 (Applications of Hydraulics) pertains to surface water. The chapter, the unit of publication, is limited to a narrow field of subject matter. This format permits flexibility in revision and publication as the need arises.

Reports in the Techniques of Water-Resources Investigations series, which are listed below, are online at http://water.usgs.gov/pubs/twri/. Printed copies are for sale by the USGS, Information Services, Box 25286, Federal Center, Denver, Colorado 80225 (authorized agent of the Superintendent of Documents, Government Printing Office), telephone 1-888-ASK-USGS. Please telephone 1-888-ASK-USGS for current prices, and refer to the title, book number, chapter number, and mention the "U.S. Geological Survey Techniques of Water-Resources Investigations." Products can then be ordered by telephone, or online at http://www.usgs.gov/sales.html, or by FAX to (303)236-469 of an order form available online at http://mac.usgs.gov/isb/pubs/forms/. Prepayment by major credit card or by a check or money order payable to the "U.S. Geological Survey" is required.

## **Book 1. Collection of Water Data by Direct Measurement**

### Section D. Water Quality

- 1–D1. Water temperature—Influential factors, field measurement, and data presentation, by H.H. Stevens, Jr., J.F. Ficke, and G.F. Smoot: USGS–TWRI book 1, chap. D1. 1975. 65 p.
- 1–D2. Guidelines for collection and field analysis of ground-water samples for selected unstable constituents, by W.W. Wood: USGS–TWRI book 1, chap. D2. 1976. 24 p.

### **Book 2. Collection of Environmental Data**

### Section D. Surface Geophysical Methods

- 2–D1. Application of surface geophysics to ground-water investigations, by A.A.R. Zohdy, G.P. Eaton, and D.R. Mabey: USGS–TWRI book 2, chap. D1. 1974. 116 p.
- 2–D2. Application of seismic-refraction techniques to hydrologic studies, by F.P. Haeni: USGS–TWRI book 2, chap. D2. 1988. 86 p.

## Section E. Subsurface Geophysical Methods

- 2–E1. Application of borehole geophysics to waterresources investigations, by W.S. Keys and L.M. MacCary: USGS–TWRI book 2, chap. E1. 1971. 126 p.
- 2–E2. Borehole geophysics applied to ground-water investigations, by W.S. Keys: USGS–TWRI book 2, chap. E2. 1990. 150 p.

## Section F. Drilling and Sampling Methods

2–F1. Application of drilling, coring, and sampling techniques to test holes and wells, by Eugene Shuter and W.E. Teasdale: USGS–TWRI book 2, chap. F1. 1989. 97 p.

## **Book 3. Applications of Hydraulics**

#### Section A. Surface-Water Techniques

- 3–A1. *General field and office procedures for indirect discharge measurements*, by M.A. Benson and Tate Dalrymple: USGS–TWRI book 3, chap. A1. 1967. 30 p.
- 3–A2. *Measurement of peak discharge by the slope-area method*, by Tate Dalrymple and M.A. Benson: USGS–TWRI book 3, chap. A2. 1967. 12 p.
- 3–A3. *Measurement of peak discharge at culverts by indirect methods*, by G.L. Bodhaine: USGS–TWRI book 3, chap. A3. 1968. 60 p.
- 3–A4. *Measurement of peak discharge at width contractions by indirect methods,* by H.F. Matthai: USGS-TWRI book 3, chap. A4. 1967. 44 p.
- 3–A5. *Measurement of peak discharge at dams by indirect methods*, by Harry Hulsing: USGS–TWRI book 3, chap. A5. 1967. 29 p.
- 3–A6. *General procedure for gaging streams*, by R.W. Carter and Jacob Davidian: USGS–TWRI book 3, chap. A6. 1968. 13 p.
- 3–A7. Stage measurement at gaging stations, by T.J. Buchanan and W.P. Somers: USGS–TWRI book 3, chap. A7. 1968. 28 p.
- 3–A8. *Discharge measurements at gaging stations*, by T.J. Buchanan and W.P. Somers: USGS–TWRI book 3, chap. A8. 1969. 65 p.
- 3–A9. *Measurement of time of travel in streams by dye tracing*, by F.A. Kilpatrick and J.F. Wilson, Jr.: USGS–TWRI book 3, chap. A9. 1989. 27 p.
- 3–Al0. *Discharge ratings at gaging stations*, by E.J. Kennedy: USGS–TWRI book 3, chap. A10. 1984. 59 p.

- 3–A11. *Measurement of discharge by the moving-boat method,* by G.F. Smoot and C.E. Novak: USGS–TWRI book 3, chap. A11. 1969. 22 p.
- 3–A12. Fluorometric procedures for dye tracing, Revised, by J.F. Wilson, Jr., E.D. Cobb, and F.A. Kilpatrick: USGS–TWRI book 3, chap. A12. 1986. 34 p.
- 3–A13. *Computation of continuous records of streamflow*, by E.J. Kennedy: USGS–TWRI book 3, chap. A13. 1983. 53 p.
- 3–A14. *Use of flumes in measuring discharge*, by F.A. Kilpatrick and V.R. Schneider: USGS–TWRI book 3, chap. A14. 1983. 46 p.
- 3–A15. Computation of water-surface profiles in open channels, by Jacob Davidian: USGS–TWRI book 3, chap. A15. 1984. 48 p.
- 3–A16. *Measurement of discharge using tracers*, by F.A. Kilpatrick and E.D. Cobb: USGS–TWRI book 3, chap. A16. 1985. 52 p.
- 3–A17. *Acoustic velocity meter systems*, by Antonius Laenen: USGS–TWRI book 3, chap. A17. 1985. 38 p.
- 3–A18. Determination of stream reaeration coefficients by use of tracers, by F.A. Kilpatrick, R.E. Rathbun, Nobuhiro Yotsukura, G.W. Parker, and L.L. DeLong: USGS–TWRI book 3, chap. A18. 1989. 52 p.
- 3–A19. *Levels at streamflow gaging stations*, by E.J. Kennedy: USGS–TWRI book 3, chap. A19. 1990. 31 p.
- 3–A20. Simulation of soluble waste transport and buildup in surface waters using tracers, by F.A. Kilpatrick: USGS–TWRI book 3, chap. A20. 1993. 38 p.
- 3–A21 Stream-gaging cableways, by C. Russell Wagner: USGS–TWRI book 3, chap. A21. 1995. 56 p.

## Section B. Ground-Water Techniques

- 3–B1. Aquifer-test design, observation, and data analysis, by R.W. Stallman: USGS–TWRI book 3, chap. B1. 1971. 26 p.
- 3–B2. Introduction to ground-water hydraulics, a programed text for self-instruction, by G.D. Bennett: USGS–TWRI book 3, chap. B2. 1976. 172 p.
- 3–B3. Type curves for selected problems of flow to wells in confined aquifers, by J.E. Reed: USGS–TWRI book 3, chap. B3. 1980. 106 p.

- 3–B4. Regression modeling of ground-water flow, by R.L. Cooley and R.L. Naff: USGS–TWRI book 3, chap. B4. 1990. 232 p.
- 3–B4. Supplement 1. Regression modeling of ground-water flow—Modifications to the computer code for nonlinear regression solution of steady-state ground-water flow problems, by R.L. Cooley: USGS–TWRI book 3, chap. B4. 1993. 8 p.
- 3–B5. Definition of boundary and initial conditions in the analysis of saturated ground-water flow systems—An introduction, by O.L. Franke, T.E. Reilly, and G.D. Bennett: USGS–TWRI book 3, chap. B5. 1987. 15 p.
- 3–B6. The principle of superposition and its application in ground-water hydraulics, by T.E. Reilly, O.L. Franke, and G.D. Bennett: USGS–TWRI book 3, chap. B6. 1987. 28 p.
- 3–B7. Analytical solutions for one-, two-, and threedimensional solute transport in ground-water systems with uniform flow, by E.J. Wexler: USGS–TWRI book 3, chap. B7. 1992. 190 p.
- 3–B8. System and boundary conceptualization in ground-water flow simulation, by T.E. Reilly: USGS–TWRI book 3, chap. B8. 2001. 29 p.

#### Section C. Sedimentation and Erosion Techniques

- 3–C1. *Fluvial sediment concepts*, by H.P. Guy: USGS–TWRI book 3, chap. C1. 1970. 55 p.
- 3–C2. Field methods for measurement of fluvial sediment, by T.K. Edwards and G.D. Glysson: USGS–TWRI book 3, chap. C2. 1999. 89 p.
- 3–C3. *Computation of fluvial-sediment discharge*, by George Porterfield: USGS–TWRI book 3, chap. C3. 1972. 66 p.

## **Book 4. Hydrologic Analysis and Interpretation**

## Section A. Statistical Analysis

- 4–A1. *Some statistical tools in hydrology*, by H.C. Riggs: USGS–TWRI book 4, chap. A1. 1968. 39 p.
- 4–A2. *Frequency curves*, by H.C. Riggs: USGS–TWRI book 4, chap. A2. 1968. 15 p.
- 4–A3. Statistical methods in water resources, by D.R. Helsel and R.M. Hirsch: USGS–TWRI book 4, chap. A3. 1991. Available only online at http://water.usgs.gov/pubs/twri/twri4a3/. (Accessed August 30, 2002.)

#### Section B. Surface Water

- 4–B1. *Low-flow investigations*, by H.C. Riggs: USGS–TWRI book 4, chap. B1. 1972. 18 p.
- 4–B2. *Storage analyses for water supply*, by H.C. Riggs and C.H. Hardison: USGS–TWRI book 4, chap. B2. 1973. 20 p.
- 4–B3. Regional analyses of streamflow characteristics, by H.C. Riggs: USGS–TWRI book 4, chap. B3. 1973.

  15 p.

## Section D. Interrelated Phases of the Hydrologic Cycle

4–D1. Computation of rate and volume of stream depletion by wells, by C.T. Jenkins: USGS–TWRI book 4, chap. D1. 1970. 17 p.

### **Book 5. Laboratory Analysis**

#### Section A. Water Analysis

- 5–A1. *Methods for determination of inorganic* substances in water and fluvial sediments, by M.J. Fishman and L.C. Friedman, editors: USGS–TWRI book 5, chap. A1. 1989. 545 p.
- 5–A2. Determination of minor elements in water by emission spectroscopy, by P.R. Barnett and E.C. Mallory, Jr.: USGS–TWRI book 5, chap. A2. 1971. 31 p.
- 5–A3. Methods for the determination of organic substances in water and fluvial sediments, edited by R.L. Wershaw, M.J. Fishman, R.R. Grabbe, and L.E. Lowe: USGS–TWRI book 5, chap. A3. 1987. 80 p.
- 5–A4. *Methods for collection and analysis of aquatic biological and microbiological samples,* by L.J. Britton and P.E. Greeson, editors: USGS–TWRI book 5, chap. A4. 1989. 363 p.
- 5–A5. Methods for determination of radioactive substances in water and fluvial sediments, by L.L. Thatcher, V.J. Janzer, and K.W. Edwards: USGS–TWRI book 5, chap. A5. 1977. 95 p.
- 5–A6. Quality assurance practices for the chemical and biological analyses of water and fluvial sediments, by L.C. Friedman and D.E. Erdmann: USGS–TWRI book 5, chap. A6. 1982. 181 p.

### Section C. Sediment Analysis

5–C1. Laboratory theory and methods for sediment analysis, by H.P. Guy: USGS–TWRI book 5, chap. C1. 1969. 58 p.

### **Book 6. Modeling Techniques**

#### Section A. Ground Water

- 6–A1. *A modular three-dimensional finite-difference ground-water flow model*, by M.G. McDonald and A.W. Harbaugh: USGS–TWRI book 6, chap. A1. 1988. 586 p.
- 6–A2. Documentation of a computer program to simulate aquifer-system compaction using the modular finite-difference ground-water flow model, by S.A. Leake and D.E. Prudic: USGS—TWRI book 6, chap. A2. 1991. 68 p.
- 6–A3. A modular finite-element model (MODFE) for areal and axisymmetric ground-water-flow problems, Part 1: Model Description and User's Manual, by L.J. Torak: USGS–TWRI book 6, chap. A3. 1993. 136 p.
- 6–A4. A modular finite-element model (MODFE) for areal and axisymmetric ground-water-flow problems, Part 2: Derivation of finite-element equations and comparisons with analytical solutions, by R.L. Cooley: USGS–TWRI book 6, chap. A4. 1992. 108 p.
- 6–A5. A modular finite-element model (MODFE) for areal and axisymmetric ground-water-flow problems, Part 3: Design philosophy and programming details, by L.J. Torak: USGS–TWRI book 6, chap. A5. 1993. 243 p.
- 6–A6. A coupled surface-water and ground-water flow model (MODBRANCH) for simulation of stream-aquifer interaction, by Eric D. Swain and Eliezer J. Wexler: USGS–TWRI book 6, chap. A6. 1996. 125 p.
- 6–A7. User's guide to SEAWAT: A computer program for simulation of three-dimensional variable-density ground-water flow, by Weixing Guo and Christian D. Langevin: USGS-TWRI book 6, chap. A7. 2002. 77 p.

## **Book 7. Automated Data Processing and Computations**

## Section C. Computer Programs

- 7–C1. Finite difference model for aquifer simulation in two dimensions with results of numerical experiments, by P.C. Trescott, G.F. Pinder, and S.P. Larson: USGS–TWRI book 7, chap. C1. 1976. 116 p.
- 7–C2. Computer model of two-dimensional solute transport and dispersion in ground water, by

- L.F. Konikow and J.D. Bredehoeft: USGS—TWRI book 7, chap. C2. 1978. 90 p.
- 7–C3. A model for simulation of flow in singular and interconnected channels, by R.W. Schaffranek, R.A. Baltzer, and D.E. Goldberg: USGS–TWRI book 7, chap. C3. 1981. 110 p.

#### **Book 8. Instrumentation**

## Section A. Instruments for Measurement of Water Level

- 8–A1. *Methods of measuring water levels in deep wells*, by M.S. Garber and F.C. Koopman: USGS–TWRI book 8, chap. A1. 1968. 23 p.
- 8–A2. Installation and service manual for U.S. Geological Survey manometers, by J.D. Craig: USGS–TWRI book 8, chap. A2. 1983. 57 p.

### Section B. Instruments for Measurement of Discharge

8–B2. Calibration and maintenance of vertical-axis type current meters, by G.F. Smoot and C.E. Novak: USGS–TWRI book 8, chap. B2. 1968. 15 p.

## **Book 9. Handbooks for Water-Resources Investiga-**

# Section A. National Field Manual for the Collection of Water-Quality Data

- 9–A1. National field manual for the collection of water-quality data: Preparations for water sampling, by F.D. Wilde, D.B. Radtke, Jacob Gibs, and R.T. Iwatsubo: USGS–TWRI book 9, chap. A1. 1998. 47 p.
- 9–A2. National field manual for the collection of water-quality data: Selection of equipment for water sampling, edited by F.D. Wilde, D.B. Radtke, Jacob Gibs, and R.T. Iwatsubo: USGS–TWRI book 9, chap. A2. 1998. 94 p.
- 9–A3. National field manual for the collection of water-quality data: Cleaning of equipment for water sampling, edited by F.D. Wilde, D.B. Radtke, Jacob Gibs, and R.T. Iwatsubo: USGS–TWRI book 9, chap. A3. 1998. 75 p.
- 9–A4. National field manual for the collection of water-quality data: Collection of water samples, edited by F.D. Wilde, D.B. Radtke, Jacob Gibs, and R.T. Iwatsubo: USGS–TWRI book 9, chap. A4. 1999. 156 p.
- 9–A5. National field manual for the collection of water-quality data: Processing of water samples, edited by F.D. Wilde, D.B. Radtke,

- Jacob Gibs, and R.T. Iwatsubo: USGS-TWRI book 9, chap. A5. 1999, 149 p.
- 9–A6. National field manual for the collection of water-quality data: Field measurements, edited by F.D. Wilde and D.B. Radtke: USGS–TWRI book 9, chap. A6. 1998. Variously paginated.
- 9–A7. National field manual for the collection of water-quality data: Biological indicators, edited by D.N. Myers and F.D. Wilde: USGS–TWRI book 9, chap. A7. 1997 and 1999. Variously paginated.
- 9–A8. National field manual for the collection of water-quality data: Bottom-material samples, by D.B. Radtke: USGS–TWRI book 9, chap. A8. 1998. 48 p.
- 9–A9. National field manual for the collection of water-quality data: Safety in field activities, by S.L. Lane and R.G. Fay: USGS–TWRI book 9, chap. A9. 1998. 60 p.