Fall 2015

Water Resource Systems Analysis - University of Kentucky, Lexington

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CE665
WATER RESOURCE SYSTEMS ANALYSIS

INSTRUCTOR

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COURSE DESCRPTION

Application of systems analysis, mathematical modeling, numerical analysis, and optimization in water resources planning, design, construction, management and operation. Solution of engineering problems found in water supply, water and wastewater treatment, urban drainage, and river basin development and management by use of linear, nonlinear, and dynamic programming models.

COURSE OBJECTIVES

1. To provide the student with a basic overview of systems analysis along with a discussion of various water resource systems.
2. To provide the student with a basic overview of knowledge engineering and current methods for use for stakeholder engagement
3. To provide the student with a basic overview of the concepts of mathematical modeling including the construction and application of both inductive and deductive computer models.
4. To provide the student with a basic overview of economic analysis as applied to water resource systems.
5. To provide the student with a basic overview of inductive models for water resource systems, including numerical methods for model applications.
6. To provide the student with a basic introduction to the use of stochastic methods in water resources including water demand and streamflow forecasting.
7. To provide the student with a basic overview of deductive models for water resource systems, including numerical methods for model applications.
8. To provide the student with a basic overview of presciptive models for water resource systems, including both analytical and numerical numerical methods for solution.

GRADING

The grade for the course will be based on the following distribution:

Homework	30%
Quizzes	40%
Term Project	20%
Project Presentation	10%

The university grade system as defined in the general school catalog will be applied to determine the corresponding letter grade.

HOMEWORK

Homework assignments will be made regularly throughout the semester. Late homework may be turned in for evaluation but will not be counted toward the final grade unless accompanied by a university approved excuse.

TERM PROJECT

Each student will be required to apply a particular optimization method to a selected water resources/environmental system, prepare a report, and make an oral class presentation.

TEXTBOOKS/CLASS NOTES

Class lectures will be drawn from the following textbooks as well as from class handouts.

[1] Mays, L, and Tung, Y., Hydrosystems Engineering and Management, Water Resources Publications, LLC, P.O. Box 260026, Highlands Ranch, Colorado, 80163-0026: ISBN 1-887201-32-7

[2] Fogler, S., LeBlanc S., Strategies for Creative Problem Solving, Prentice Hall, New Jersey, ISBN 0-13-179318-7

[3] Chapra, S., Canale, Raymond, Numerical Methods for Engineers,Sixth Edition, McGraw Hill, 1221 Avenue of the Americas, New York, NY 10020, ISBN 0-07-291873-X

[4] Belegundu, A., and Chandrupatla, T., Optimization Concepts and Applications in Engineering, Prentice Hall Inc., Simon & Schuster, Upper Saddle River, New Jersey 07458, ISBN 0-13-031279-7

BIBLIOGRAPHIES

Much of the material that we will be covering in the class, has not made it yet into textbooks. As a result, an extensive bibliography of relevant journal articles and reports is provided in support of the topics to be covered.

SOFTWARE

www.ece.northwestern.edu/OTC/

www.lindo.com

www.solver.com

www.iseesystems.com/

CE699 General Guidelines for Homework

1. General format for each problem should include:

    a. problem statement
    b. methodology
    c. results
    d. discussion
    e. summary/conclusions

2. Provide a printed layout of any spreadsheets used, including descriptions of all rows and columns.

3. Be sure to provide written descriptions of variables/equations.

4. All tables and figures should be labeled and referenced in descriptive text.

5. Figures should be labeled at the bottom. Tables should be labeled at top.

6. Figures and Tables should be oriented top to bottom or left margin to right margin.

7. All items in tables and figures should have appropriate and identified units.

8. All data sources should be referenced (including those from web).

CE699 Report Contents

1. Introduction
2. Problem Statement
3. Mathematical Formulation of Problem
4. Discussion of Numerical/Optimization Methods Used
5. Discussion of Analysis
6. Presentation of Results
7. Discussion of Results
8. Discussion of Results
9. Conclusions/Recommendations

CE699 Report Format Guidelines

All reports should be written consistent with the Report Writing Style Guide for Engineering Students by Anne Winckel and Bonnie Hart with the University of South Australia (see dropbox).

Dropbox

Class assignments, lecture notes, models, and supporting publications will be provided in a class dropbox for access by members of the class. Each student is responsible for downloading and keeping up with the associated assignments.

CE 699 COURSE OUTLINE

1. Introduction to Water Resources Engineering ([1], Handouts)

2. Introduction to the System Approach ([2], Handouts)

3. Knowledge Engineering (Handouts)

    A. Stakeholder Engagement
        1) Community Based Participatory Communication
        2) Structured Public Involvement
        3) Casewise Visual Evaluation
    B. Collaborative Modeling
    C. Expert Systems

4. Introduction to Water Resource Modeling (Handouts)

    A. Conceptual Models
    B. Mathematical Models
        1) Model Formulation
            1) Inductive Models
            2) Deductive Models
                a) Deterministic Models
                b) Empirical Models
        2) Model Construction
        3) Model Verification
        4) Model Calibration
        5) Model Validation
        6) Model Application
    C. Modeling Challenges
    D. Model Selection
    E. Model Case Studies

Bibliography on Stakeholder Engagement

Arnstein, Sherry R. "A Ladder of Citizen Participation," JAIP, Vol. 35, No. 4, July 1969, pp. 216-224.

Rawls, J. 1971. *A Theory of Justice.* Cambridge: Harvard University Press.

Rawls, J. 2001. *Justice as Fairness: A Restatement.* Cambridge: Harvard University Press.

Beierle, T.C. and Cayford, J. 2002. *Democracy in Practice: Public Participation in Environmental Decisions*. Resources for the Future. Washington, DC.

U.S. DOE, An Evaluation of DOE-EM Public Participation Programs, February 2003

Proceedings of the Champions of Participation, March 30-31, 2009

Energy Communities Alliance, 2007. *The Politics of Cleanup – Lessons Learned from Complex Federal Environmental Cleanups*, Energy Communities Alliance, Inc.

Ormsbee, L. and Hoover, A. 2010. "End State Vision Process for the Paducah Gaseous Diffusion Plant." Proceedings of *World Environmental and Water Resources Congress 2010.* Providence, R.I. May 16-20.

Ormsbee, L., et al., (2011) UK-KRCEE, Community Visions for the Paducah Gaseous Diffusion Plant Site, UK/KRCEE Doc#P25.1

Bibliography of Community Based Participatory Communication

Chike Anyaegbunam, Ph.D., Anna Hoover, & Mitchael Schwartz, (2010) Use of community-based participatory communication to identify community values at a Superfund site, *Proceedings of the World Environmental and Water Resources Congress 2010*.

Anyaegbunam, C., Mefalopulos, P., & Moetsabi, T. (2004). *Participatory Rural Communication Appraisal: A handbook for rural development practitioners.* 2nd edition. FAO Rome, Italy.

Downey, L., Anyaegbunam, C., Scutchfield, (2009) Dialogue to Deliberation: Expanding the Empowerment Education Model, Am J Health Behaviors, 33(10): pp 22-36.

Bibliography of Structured Public Involvement

Blandford, B., Bailey, K., Grossardt T. and Ripy, J. 2008. Integrated Transportation and Land Use Scenario Modeling by Visual Evaluation of Examples: Case Study of Jeffersonville, Indiana. *Transportation Research Record* 2076:192-208.

Grossardt, T., Ripy, J. and Bailey, K. 2010. Use Of Structured Public Involvement For Identifying Community Preferences For A Superfund Site End State Vision. *Proceedings of the World Environmental and Water Resources Congress 2010*.

Bibliography of Casewise Visual Evauation

Bailey, K., Brum, J. and Grossardt, T. 2001. Towards Structured Public Involvement in Highway Design: A Comparative Study of Visualization Methods and Preference Modeling Using CAVE (Casewise Visual Evaluation). *Journal of Geographic Information and Decision Analysis* 5(1):1-15.

Bailey, K., Grossardt, T. and Pride-Wells, M. 2007. Community Design of a Light Rail Transit-Oriented Development using Casewise Visual Evaluation (CAVE). *Socio-Economic Planning Sciences* 41(3): 235-254.

Bailey, K., Grossardt, T., Williams, J., Toole, L. and Bryant, B. 2007. Context-sensitive large bridge design using Casewise Visual Evaluation: Case Study Section 2 Ohio River Bridges Project. *Transportation Research Record* 2028:85-92.

Bibliography of Collaborative Modeling

Langsdale, S. (Chair) (2010) ASCE Task Committee: Principles and Best Practices for Collaborative Modeling for Decision Support in Water Resources

Lorie, M., Werick, B., Sanderson, J., (2010) Collaborative Modeling for Water Supply Controversies in Colorado: Technical Challenges and Lessons Learned, *Proceedings of the World Environmental and Water Resources Congress 2010*.

Cardwell, H., Langsdale, S., (2011), Collaborative Modeling for Decision Support - Definitions and Next Steps, *Proceedings of the World Environmental and Water Resources Congress 2011*.

Langsdale, S., Bourget, L., (2009) Developing Best Practices for Computer Aided Dispute Resolution, *Proceedings of the World Environmental and Water Resources Congress 2009*.

Langsdale, S., Michaud, W., Does Collaborative Modeling Lead to Better Management of Our Water Resources, *Proceedings of the World Environmental and Water Resources Congress 2009*.

Voinov, A., Cox, W., Cardwell, H., (2007) "Pilot Collaborative Modeling Study for Regulatory Issues on the James River, *Proceedings of the World Environmental and Water Resources Congress 2007*.

Keifer, J., Werick, B., Cardwell, H., (2007) A Review of Computer - Aided Stakeholder Collaboration in Water Resources Planning and Management, *Proceedings of the World Environmental and Water Resources Congress 2007*.

Bibliography of Knowledge Engineering Applications

Ramesh S.V. Teegavarapu, Anil Tangirala, and Lindell Ormsbee. (2003) MIST (Model Identification and Selection Tool): A knowledge-based System for Selection of Water Quality Models, Published in CDROM Proceedings, 40704-008-004, in Design and Decision Support Tools, 11 pages, 4th Information Technology Symposium, ASCE, November, 2003.

Jain, A., and Ormsbee, L., (2001) "A Decision Support System for Drought Characterization and Management," Civil Engineering and Environmental Systems, Vol 18 (2), pp. 105-140.

Ormsbee, L.E., (1989) "Rainfall Disaggregation for Continuous Hydrologic Modeling," *ASCE Journal of Hydraulic Engineering*, Vol. 115 (4), pp. 507-528.

Ormsbee, L., (2005) "Drought Planning and Management Experiences in the Kentucky River Basin", *Proceedings of the World Environmental and Water Resources Congress 2005*.

Water Expert: http://expert.ei.ua.edu/

Examples of Model Calibration

Moriasi, D., Arnold, J., Van Liew, M., Bingner, R., Harmel, D., Veith, T., (2007) Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations, American Society of Agricultural and Biological Engineers, Vol 50 (3), pp. 885-900.

Nash, J.E. and J.V. Sutcliffe. River flow forecasting through conceptual models, I: A discussion of principles. *Journal of Hydrology*, 10: 282-290. Nathan, R.J. and T.A. McMahon. 1990.

Donigian, A.S. Jr., J.C. Imhoff, B.R. Bicknell, and J.L. Kittle, Jr. 1984. Application Guide for Hydrological Simulation Program – FORTRAN (HSPF). EPA-600/3-84-065. Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA.

Ormsbee, L, and Lingireddy, S., (1997) "Calibrating Hydraulic Network Models," *Journal of the American Water Works Association"*, Vol 89, (2), pp 42-50, Times Cited: 12**.**

5. Economic Models [1]
   - A. Concept of Interest/Rates
   - B. Cash Flow Diagrams
   - C. Economic Analysis
   - D. Project Analysis
   - E. Market Economics
   - F. Welfare Economics

6. Introduction to Prescriptive Models [2, 3, 4]

   - A. Optimality Conditions
   - B. Univariate Optimization
     1) Newton's Method
     2) Secant Method
     3) False Position Method
     4) Bisection Method
     5) Polynomial Interpolation
     6) Golden Section Method
   - C. Analytical Methods for Unconstrained Optimization
     1) Newton's Method
     2) Steepest Descent Method
     3) Conjugate Gradient Method
     4) Davidon Fletcher Powell Method
   - D. Analytical Methods for Constrained Optimization
     1) Substitution Method
     2) Lagrange Multiplier Method

Quiz 1

7. Numerical Methods for Inductive Models [1], [Handouts]

A. Deterministic Models

1) Interpolation Analysis
   a) Reservoir design application
   b) Manning's equation approximation
2) Regression Analysis
   a) Demand forecasting application
3) Neural Network Analysis
   a) Watershed model application
4) GP/GA Function Analysis
   a) Stream water quality application

B. Stochastic Models [1], [Handouts]

1) Probability Theory
   a) Pathogen modeling application
2) Frequency Analysis
   a) Flood prediction application
3) Hypothesis Testing
   a) Stream Water Quality
3) Time Series Analysis
   a) Demand forecasting application
   b) Streamflow forecasting application

Quiz 2

Applications of Inductive Models

Lingireddy, S., and Ormsbee, L., (1998) "Neural Networks in Optimal Calibration of Water Distribution Systems, in *Artificial Neural Networks for Civil Engineers: Advanced Features and Applications,* ASCE, 227 pp.

Teegavarapu, R., Tufail, M., and Ormsbee, L., (2009) "Optimal Functional Forms for Estimation of Missing Precipitation Data," *Journal of Hydrology,* Volume, 374, (1-2), July, PP. 106-115.

Tufail, M., Ormsbee, L.E., and Teeagavarapu, R. (2008) "Artificial Intelligence (AI)-based Inductive Models for Prediction and Classification of Fecal Coliform in Surface Waters." *ASCE Journal of Environmental Engineering,* Vol 134, (9), pp. 789-799.

Tufail, M., and Ormsbee, L., (2006) "A Fixed Functional Set Genetic Algorithm (FFSGA) Approach for Function Approximation"*, IWA Journal of Hydroinformatics,* Vol. 8, (3), pp 193-206.

Jain, A. and Ormsbee, L.E., (2004) "Evaluation of the Available Techniques for Estimating Missing Fecal Coliform Data", *J. Amer. Wat. Resour. Assoc.* Vol 40, (6),Times Cited: 6.

Ormsbee, L., Elshorbagy, A.,and Zechman, E., (2004) "Methodology for pH TMDLs: Application to Beech Creek Watershed," ASCE *Journal of Environmental Engineering*, Vol. 130, (2), Times Cited: 6.

Jain, A., and Ormsbee, L. (2002) "Short-term Water Demand Forecast Modeling Techniques- Conventional Methods Versus AI", *Journal of the American Water Works Association*, Vol 94, (7), pp. 64-72, Times Cited: 28.

Ormsbee, L., Balla, A. Teegavarapu, R., (2007) "Evaluation of Spatial Interpolation Techniques for Estimation of Missing Precipitation Data," Annual Conference of the American Institute of Hydrology, Reno, Nevada, October 17-20th, 2007

Balla, A., Teegavarapu, R. Viswanathan, C., and Ormsbee, L., (2007) "Evaluation of Spatial Interpolation Techniques for Estimation of Missing Precipitation Data." ASCE/EWRI World Water Congress, Tampa, May 15-19, 2007

Ormsbee, L., and Tufail, M," Comparison of Artificial Intelligence (AI) Techniques to Develop Functional Relationships for Water Quality Loadings," (2004) Annual Conference of the EWRI, Salt Lake City, June 27-30, 2004.

8. Numerical Methods for Deductive Models [1],[3], [Handouts]

A. Deterministic Models

1) Numerical Solution of Nonlinear Equations
   a) Normal depth application
   b) Green Ampt equation
   c) Nonlinear reservoir runoff application
   d) Pipeline design
2) Numerical Integration
   a) Stream area application
   b) Hydrograph volume application
3) Numerical Solution of Differential Equations
   a) Draining Tank
   b) Reservoir routing application
4) Numerical Solution of Partial Differential Equations
   a) Groundwater modeling application
   b) Flood routing applications
5) Systems of Linear Equations
   a) Hydrograph translation application
   b) Reactor Application
6) Numerical Solution of Nonlinear Sets of Equations
   a) Water distribution application
      1) Steady state analysis
      2) Transient analysis
      3) Water Quality analysis

Quiz 3

Applications of Deterministic Models

Blandford, G. E., and Ormsbee, L.E., (1992) "A Diffusion Wave Finite Element Model for Channel Networks," *Journal of Hydrology*, Vol. 142 (1), pp. 99-120.

Ormsbee, L.E. and Khan, A.Q., (1989) "A Parametric Model for Steeply Sloping Forested Watersheds," *Water Resources Research*, Vol. 25 (9), pp. 2053-2065.

Khan, A.Q. and Ormsbee, L.E., (1989) "A Comparison of Two Hydrologic Models for Steeply Sloping Forested Watershed," *Journal of Hydrology*, Vol. 109 (3-4), pp. 325-349.

Ormsbee, L.E. Delleur, J.W., and Houck, M.H., (1987) "Design of Stormwater Detention Basins for Multiple Design Frequencies," *ASCE Journal of Hydraulic Engineering*, Vol. 113 (5), pp. 601-614.

Ormsbee, L.E. and Wood, D.J., (1986) "Hydraulic Design Algorithms for Pipe Networks," *ASCE Journal of Hydraulic Engineering*, Vol. 112 (12), pp. 1195-1207.

Ormsbee, L.E. and Wood, D.J., (1986) "Explicit Pipe Network Calibration," *ASCE Journal of Water Resources Planning and Management*, Vol. 112 (2), pp. 166-182.

9. Numerical Methods for Optimization Analysis [1], [2], [3], [Handouts]
    - A. Optimality conditions
    - B. Unconstrained Optimization
        - 1) Pattern Search Methods
            - a. Simplex Method
            - b. Hooke Jeeves Method
            - c. Fletcher Powell Patterned Search
        - 2) Evolutionary Methods
            - a. Genetic Optimization
            - b. Ant Colony Method
            - c. Particle Swarm Method
    - C. Constrained Methods
        - 1) Generalized reduced gradient method
        - 2) Penalty function methods
        - 3) Box complex method
            - a. Detention basin design
            - b. Hydraulic network model calibration
            - c. Hydraulic network design
            - d. Optimal pump scheduling
            - e. Activated sludge design
    - D. Linear Programming
        - 1) Problem Formulation
        - 2) Solution Methods
            - a. Graphical
            - b. Sequential Equation
            - c. Matrix methods
                - 1) Simplex Algorithm
                - 2) Revised Simplex Algorithm
            - d. Applications
                - 1) Regional wastewater
                - 2) Hydraulic network design
                - 3) Reliability design
                - 4) Reservoir operation
    - E. Integer/Mixed Integer Programming
        - 1) Branch and Bound Algorithm
        - 2) Applications
            - a. Coverage problem
            - b. Production problem
    - F. Dynamic Programming

1) Pipeline design
2) Reservoir operation
3) Detention basin design

G. Stochastic Programming
1) Stochastic DPs
2) Chance constrained LPs

Quiz 4

Applications of Optimization Models

Tufail, M., and Ormsbee, L.E., (2009) "Optimal Water Quality Management Strategies for Urban Watersheds Using Macro-Level Simulation and Optimization Models, *ASCE Journal of Water Resources Management*, Volume 135 (4), July/August, pp. 276-285.

Ormsbee, L., Lingireddy, S., Chase, D., (2009) "Optimal Pump Scheduling for Water Distribution Systems", Multidisciplinary International Scheduling Conference: Theory and Applications, Dublin, Ireland, August 1-12, 2009.

Ormsbee, L, Tufail, M. (2007) "A Shuffled Box Complex-based Optimization Model for Watershed Management" ASCE/EWRI World Water Congress, Tampa, May 15-19, 2007

Lingireddy, S., and Ormsbee, L., (2002) "Hydraulic Network Calibration using Genetic Optimization," *Civil and Environmental Engineering Systems*, Vol. 19 (1), pp. 13-39.

Ormsbee, L.E., and Reddy, S. L., (1995) "Nonlinear Heuristic for Pump Operations," *ASCE Journal of Water Resources Planning and Management*, Vol. 121, (4), pp. 302-309.

Ormsbee, L.E., and Lansey, K.E., (1994) "Optimal Control of Water Supply Pumping," *ASCE Journal of Water Resources Planning and Management*, Vol. 120, (2), pp. 237-252.

Boulos, P., and Ormsbee, L. (1991) "Explicit Network Calibration for Multiple Loading Conditions," *Civil Engineering Systems*, Vol. 8 (3), pp. 153-160.

Kessler, A., Ormsbee, L., and Shamir, U., (1990) "A Methodology for Least-Cost Design of Invulnerable Water Distribution Networks," *Civil Engineering Systems*, Vol. 7 (1), pp. 20-28.

Ormsbee, L.E. and *Kessler, A.*, (1990) "Optimal Upgrading of Hydraulic Network Reliability," *ASCE Journal of Water Resources Planning and Management*, Vol. 116 (6), pp. 784-802, Times Cited: 15.

Ormsbee, L.E., (1989) "Implicit Pipe Network Calibration," *ASCE Journal of Water Resources Planning and Management*, Vol. 115 (4), pp. 243-257

Ormsbee, L.E., Houck, M.H., and Delleur, J.W., (1987) "Design of Dual-Purpose Detention Systems Using Dynamic Programming," *ASCE Journal of Water Resources Planning and Management*, Vol. 113 (2), July, 1987, pp. 471-484.

Ormsbee, L.E., "A Nonlinear Heuristic for Applied Problems in Water Resources," *Proceedings of the Seventeenth Annual Pittsburgh Conference on Modeling and Simulation*, Pittsburgh, PA, April 24-25, 1986, pp. 1117-1121.