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Ground-water policy-making support: USEM Optimization Modelling plus GIS and graphics

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Ground-water Policy-making Support:
USEM Optimization Modeling Plus GIS and Graphics

Richard C. Peralta1, A.M., ASCE, Christopher M. U. Neale1, A.M., Ali Gharbi1, Mazibur Khan1, Oscar Daza1, Douglas Ramsey2 and Kurt Vest1

Abstract

A support tool for ground-water management decision making involves integration of a multiobjective optimization model, GIS and graphics software. Two results are improved consideration of spatial data within the optimization model and improved conversion of optimal strategies to real-world application. Another result is improved visualization of the trade-offs involved between conflicting management goals.

Introduction

Assuring the sustained availability of groundwater of adequate quality and quantity requires integrating efforts of many agencies. This is so because contaminant movement is affected by ground-water pumping and vice versa. Contaminant movement can also be affected by use of approved site-specific water and chemical Best Management Practices, land uses or well-head protection regulations. Furthermore, in some locations, the legal right to use groundwater might be retained only to the extent that such use is sustainable and does not cause damage to others.

This paper demonstrates how a geographic information system (GIS) and graphics tools can be used to help integrate multiple agency goals for long-term ground-water management in the Salt Lake Valley. These tools facilitate use of the USEM (Utah State EMbedding) model, which computes optimal sustained yield ground-water...
management strategies. The computed optimal strategies satisfy restrictions which reflect agency objectives, water flow and contaminant transport.

Computing Optimal Ground-water Management Strategies using USEM

USEM is a modified version of a model previously described by Gharbi et al. (1990) and Peralta et al. (1991). USEM is an operations research style of optimization model which includes an objective function, constraint equations, and limits on variables. The objective function includes either a single objective (i.e. maximizing ground-water pumping) or multiple objectives. At present, explicit multiple objectives include: (1) maximizing ground-water pumping and (2) minimizing future exceedance of target contaminant concentration values. Weighting coefficients are used to emphasize attaining one objective over another.

Constraints include representation, through embedded finite difference equations, of steady and transient flow processes. Represented are: ground-water flow, evapotranspiration, flow from drains, stream-aquifer interflow and boundary flows. Other constraints use embedded finite element equations to describe contaminant transport and future concentrations.

Utilized limits on variables (or sums of variables) most commonly include those on ground-water pumping, potentiometric and ground-water flow magnitudes and directions. These bounds (or constraints) reflect goals of several agencies. For example, agencies responsible for water supply or water rights agencies sometimes desire to prevent excessive drawdowns. Other agencies might want to prevent water tables from rising too near to the ground surface and contacting existing contamination. Another agency might wish to keep water levels high to maintain baseflow to streams.

Processing and Interpreting Optimal Strategies using GIS and Graphical Software

USEM computes optimal sustainable ground-water pumping (extraction) strategies and the future heads that will result within a study area. Figure 1 illustrates sample results for Salt Lake Valley (cells range in size from 1.3 to 2.6 sq km). It shows drawdowns in the potentiometric surface by the end of the planning horizon and shows whether optimal pumping values are greater or less than current pumping. Contours are developed using SURFER (GSI, 1990).

Figure 2 shows sample results of using ARC/INFO (ESRI, 1989) to process the optimal pumping values for the area. ARC/INFO is a vector based GIS that integrates a
data base management system (INFO) with a spatial mapping system (ARC). ARC/INFO is used for compatibility with other agencies in Utah, even though it does not deal with gridded data as easily as does a vector based system. Using ARC/INFO will also facilitate overlaying other vector based data available for Salt Lake Valley.

Fig. 1. Drawdown Contours in the Principal Aquifer after 20 Years of Optimal Ground-water Pumping (ft), and Comparison between Optimal Pumping and Current Pumping (To convert to meters multiply by 0.305.)
Figure 3 illustrates a type of graphic important for presentation to decision makers. It shows a hypothetical range of optimal solutions to the multiobjective optimization problem. This exaggerated figure demonstrates to managers a conflict between attempting to maximize sustainable ground-water extraction and preventing the increase in ground-water contamination at
specific locations. This problem occurs because maximizing pumping usually increases drawdowns and hydraulic gradients, speeding contaminant migration.

![Pareto Optimum](image)

**Fig. 3.** Pareto Optimum of Conflicting Objectives for Maximizing Sustainable Ground-water Pumping and Minimizing Average Increase in Ground-water Contamination at Control Locations

**Anticipated GIS Uses with USEM**

In the future, ARC/INFO, or other GIS, will be used increasingly to formulate the optimization problems addressed by USEM. A GIS's unique ability to handle spatial and tabular data (soils, crops, water use, water rights, wells, land use, and others) in coverages that can be overlain, make it an ideal tool for generating input data for USEM. The same attributes will be increasingly utilized in producing products (such as maps) from USEM output.

These enhancements are important because the USEM discretization (cell grid), required for computational efficiency, is not ideal for real-world decision-making. For example, USEM output can help determine cells where a specific Best Management System (combination of irrigation efficiency and pesticide use) might be desired (to avoid ground-water contamination). However, one would probably not want to restrict water/chemical use in an entire cell. It is preferable to be able to adjust the boundaries of a restricted use area appropriately—within individual cells. That is where GIS capabilities can be very helpful.

Similarly, combining the abilities of USEM and GIS can aid water supply planning. USEM can help determine how much groundwater and surface water should be used in each cell. Ultimately however, water supply decisions should consider water service area pressure zones, which
are not generally described using a rectangular grid (Bishop et al. 1988). Converting cell-based optimal strategies into in-cell recommendations is important.

Summary

Long-term ground-water management is enhanced by use of optimization models, such as USEM, which consider both management goals and physical processes appropriately. However, the practical utility of such models is sometimes lessened because of the spatial discretization they use. To lessen computational difficulties, USEM uses a fairly regular or simplified spatial discretization scheme.

Linking USEM with other software can improve its utility. A GIS can process complex spatially variable data and prepare input in a discretization useful for USEM. Similarly, a GIS can help process optimal water use strategies (consisting of a separate value of ground water or surface water use for each cell) into in-cell distributions more useful for practical water management.

Systematic decision making is aided by enhancing data development and presentation. Data development and presentation are enhanced by coupling optimization models, GIS, and graphics software. The result of these activities should be improved water management policies.

Acknowledgments

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Appendix I.-References


A NATIONAL CONFERENCE ON:

- HYDRAULIC ENGINEERING
- ENVIRONMENTAL ENGINEERING
- WATER RESOURCES, PLANNING & MANAGEMENT
- IRRIGATION & DRAINAGE

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International Association of Hydrogeologists
International Commission on Large Dams
Korean Society of Civil Engineers
National Water Resources Association
Norwegian Society of Chartered Engineers
Perm. Int'l. Assoc. of Navigation Congresses
Societas Internationalis Limnologii
Societe Des Ingenieurs De France
The Institution of Engineering, Pakistan
The Institution of Engineers of Ireland
The Institution of Engineers, Australia
The Institution of Structural Engineers
The Union of Int'l. Technical Associations
The Universities Council on Water Resources
U.S. Committee on Irrigation and Drainage
U.S. Geological Survey
US Net. Comm. IAWPRC
Verein Deutcher Ingenieure

Aerial View of Baltimore
Is an Instream Flow Need a Beneficial Use?: ROBERT T. MILHOUS, National Ecology Research Center, Ft. Collins, CO
Are High and Low Flow Habitat Values Really the Same?: T.J. WADDLE, National Ecological Research Center, Ft. Collins, CO
River Basin Level Hydroelectric Development: Hydropower, Water Quality and Waste Discharge: SHU-YUN CHANG, North Carolina A&T University, Greensboro, NC; SHU-LIANG LIAN, Tamkang University, Taipei, Taiwan, ROC; and STEVEN F. RAILSBACK and MICHAEL J. SALE, Oak Ridge National Laboratory, Oak Ridge, TN

SESSION: ID01  Ballroom C
IRRIGATION TECHNOLOGY TRANSFER IN DEVELOPING COUNTRIES: PART 1
Presiding: CHARLES BURT, California Polytechnic State University, San Luis Obispo, CA
The Debate Over Modernization: HERVE PLUSQUELLEC, The World Bank, Washington, DC; and CHARLES BURT, California Polytechnic State University, San Luis Obispo, CA
Technology Transfer Lessons From a U.S. Water District: DOUGLAS WELCH, Imperial Irrigation District, Imperial, CA
Technology Transfer For Projects In South America: JOSEPH B. SUMMERS, Summers Engineering, Inc., Hanford, CA
Intensive Irrigation Projects in Spain: ELIAS FERERES, CIDA, SPAIN

SESSION: ID02  Ballroom E
DRAINAGE IN THE HUMID AREAS
Presiding: RICHARD D. WENBERG, Fairfax Station, VA
Environmental Impacts of Agricultural Drainage: R.W. SKAGGS, M.A. BREVE and J.W. GILLIAM, North Carolina State University, Raleigh, NC
Engineering of Controlled Drainage Systems: J.L. FOSS, J.R. ROGERS and C.E. CARTER, USDA-ARS, Baton Rouge, LA
Optimizing Economic Returns in Drainage Design: LARRY D. GEOHRING, Cornell University, Ithaca, NY
Stochastic Analysis of Seasonal Hydraulic Conductivity: RAM K. GUPTA, RAMESH P. RUOY and W.TREVOR DICKINSON, University of Guelph, Ontario, Canada; NAIVEN K. PATNI, Agriculture Canada, Ottawa, Canada; and GREG WALL, Agriculture Canada, Guelph, Ontario, Canada

SESSION: ID07  Ballroom F
GROUND WATER QUANTITY/QUALITY IN THE U.S.
Presiding: RICHARD C. PARALTA, Utah State University, Logan, UT
Ground Water Management in Southern Florida: MARK M. WILSNACK, South Florida Water Management District, West Palm Beach, FL
Ground Water Management in Arkansas: JONATHAN RAY SWEENEY, Arkansas Soil and Water Conservation Commission, Little Rock, AR; and A. MARK BENNETT III, University of Arkansas, Fayetteville, AR

SESSIOm EE30  Columbia
INDUSTRIAL WASTEWATER ISSIONS
Presiding: IRA WHITMAN, Whitman Companies, East Brunswick, NJ

Identifying Promising Hazardous Waste Reduction Technologies: JAMES D. ENGLEHARDT, University of Miami, Coral Gables, FL
Baltimore's Industrial Pretreatment Program Has Successfully Reduced the Concentrations of Priority Pollutants Entering the Back River Waste Water Treatment Plant: GEORGE G. BALOG AND RALPH 0. CULLISON, III, City of Baltimore Dept. of Public Works, Baltimore, MD
Water Reduction Program as Justification for Permit Backsliding: GARY W. SIEGEL AND MARGARET L. Dwyer, Goldman Environmental Consultants, Randolph, MA

SESSION: EE04  Frederick
ENVIRONMENTAL ASSESSMENT ISSUES
Presiding: AMY ZLOTSKY, EA Engineering, Science, and Technology, Lincoln, NE
Case Study: How Environmental Permits Take on a Life of Their Own: LEONARD A. CILLI, Earth Technology Group, Cherry Hill, NJ; and PAUL J. COTILLA, Cotilla Associates, Plainview, NY

Permitting Refinery Heater Modifications in the South Coast Air Quality Management District: R. SAHU, T. HUNT, Engineering-Science, Pasadena, CA
Incineration — Panacea or Pandemic: HARVEY W. ROGERS, Agency for Toxic Substances and Disease Registry, Atlanta, GA
Mass Transfer and Exposure in Residential Showers: JOHN C. LITTLE, Lawrence Berkeley Laboratory, Berkeley, CA

SESSION: EE15  Annapolis
TOXIC AND HAZARDOUS MATERIALS BIOREMEDIATION
Presiding: N. SHASHOHARA, Ebasco Services, Lyndhurst, NJ
Development of a Protocol to Evaluate Volatilization and Biodegrability Characteristics of Turpene-Based Solvent Substitutes: BENERTO S. MARTINEZ, JR.; RICARDO B. JACQUEZ, and WALTER H. ZACHRITZ II, New Mexico State University, Las Cruces, NM
Emerging in Situ Technologies for Addressing Contamination in the Saturated Zone: A Way to Reduce Cleanup Periods: SUTHAN S. SUTHERSAN, Gorathiy & Miller, Plainview, NY
SESSION 5:5/8:15-9:45am Con't.

Use of Bioremediation as a Waste Minimization Process: SUTHAN S. SUTHERSAN, Geahty & Miller, Plainview, NY


A Preliminary Evaluation of Transport Mechanisms for Multiple Substrates in a Laboratory Column System: ZHIBIN XUE and WILLIAM F. MCTERNAN, Oklahoma State University, Stillwater, OK

SESSION: EE11 Baltimore

SOLID WASTE LANDFILL LINERS
Presenting: S. SAYED, Jamal & Associates, Winter Park, FL


Leakage Mechanism Through Double Liner Systems: ABDUL R. MULLA and WILLIAM F. MCTERNAN, Oklahoma State University, Stillwater, OK

Permeation of Organic Chemicals through HDPE Geomembranes: JONI P. SAKTI, JIM K. PARK, and JOHN A. HOOPES, University of Wisconsin, Madison, WI

Design of Landfill Drainage Systems: BRUCE M. McENROE, University of Kansas, Lawrence, KS

SESSION: HY-45 Convention Center 302

URBAN STORMWATER AND DETENTION


Accumulation Effects of Stormwater Management Detention Basins: R.G. TRAVER and R.A. CHADDEON, Civil Engineering Dept., Villanova University, Villanova, PA

Experiments with Wind Effects on Pavement Runoff: JOSEPH R. REED, Dept. of Civil Engineering, Penn State University, University Park, PA, DAVID F. KIBLER, Dept. of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA and G.A. KRALLIS, Whitman and Howard, Inc., Wellesley, MA


SESSION: HY-44 Convention Center 303

HYDRAULICS OF BRIDGE SCOUR

Presiding: D.J. HAGERTY, Civil Engineering Dept., University of Louisville, Louisville, KY

Seepage Influence on Stability of Bridge Abutments: D.J. HAGERTY and A.C. PAROLA, Civil Engineering Dept., University of Louisville, Louisville, KY


Seepage Effects on Bridge Pier Scour: A.C. PAROLA and D.J. HAGERTY, Civil Engineering Dept., University of Louisville, Louisville, KY

SESSION: HY-35 Convention Center 304

SEDIMENTATION AND STABLE CHANNEL DESIGN

Presiding: ROGER A. KUHNLE, USDA National Sedimentation Lab, Oxford, MS

Design of a Threshold Channel: G. VIGILAR and P. DIPLAS, Dept. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, VA

Critical Evaluation of Thickening Theories: A. PAPANICOLAOU and P. DIPLAS, Dept. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, VA

Loop Rating Curves from Goodwin Creek: R.A. KUHNLE and A.J. ODGAARD, USDA National Sedimentation Lab, Oxford, MS

Darcy-Weisbach Roughness Coefficients for Gravel and Cobbled Surfaces: J.E. GILLEY, E.R. GOTTWITZ and G.A. WEIMAN, University of Nebraska, Lincoln, NE

SESSION: HY-47 Convention Center 305

CASE STUDIES OF NATURAL DISASTERS


Floods in Bangladesh: B.K. LEE, Harza Engineering Co., Chicago, IL


SESSION: HY-13 Convention Center 306

COASTAL HYDRAULICS AND TRANSPORT

Presiding: E.R. HOLLEY, Dept. of Civil Engineering, University of Texas, Austin, TX

Model for Transport of Floating Debris in the Ocean: Y.C. SU, Espey, Huston & Associates, Inc., Austin, TX, E.R. HOLLEY and G.H. WARD, Dept. of Civil Engineering, University of Texas, Austin, TX

Model Study to Determine the Wave Forces Acting on the St. Lucie Velocity Caps: SUFIAN A. KHONDKER, Esbasco Services, Inc., New York, NY, TATSUAKI NAKATO, Institute of Hydraulic Research, University of Iowa, Iowa City, IA, H. ROGER GAVANKAR and RUDY D. GIL, Florida Power & Light Co.

Verification Techniques Used in Modeling Charleston Harbor, South Carolina: S.B. HELTZEL, USAE Waterways Experiment Station Vicksburg, MS

Erosion of a Thin Lutocline Under Homogeneous Turbulence: P.D. SCARLATOS, Dept. of Ocean Engineering, Florida Atlantic University, Boca Raton, FL
SESSION: ID29 Chesapeake B

INTENTIONAL WEATHER MODIFICATION

Presiding: DON GRIFFITH, North American Weather Consultants, Salt Lake City, UT


Results from a Long-Term Winter Cloud Seeding Program in Utah: DON GRIFFITH, JOHN R. THOMPSON and DAN A. RISCH, North American Weather Consultants, Salt Lake City, UT

The Present Status of Precipitation Enhancement by Cloud Seeding: H.T. BRUTJES, T.L. CLARK, W.D. HALL, National Center for Atmospheric Research, Boulder, CO

Cloud Seeding: The Engineering is Done, But What About Social Impacts?: MAURICE ROOCS, California Department of Water Resources, Sacramento, CA

SESSION: HY-14 Ballroom C

GROUNDWATER AND CONTAMINANT TRANSPORT

Presiding: LOUIS H. MOTZ, Dept. of Civil Engineering, University of Florida, Gainesville, FL

Groundwater Quality Model with Applications to Various Aquifers: M.M. SOLIMAN, and A. HASSAN, Ain Shams University, Cairo, EGYPT

Comparison of Numerical Modeling Approaches for Subsurface Immiscible Contaminant Transport: K. RATHFIELD and LINDA M. ABENDIO, Dept. of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI


Groundwater Modeling of Wastewater Management Options: D.N. BROCARD, Metcalf & Eddy, Inc., Wakefield, MA, and A. PROTOU, Polytechnic University of New York, Brooklyn, NY

SESSION: HY-21 Ballroom D

3-D FREE-SURFACE HYDRODYNAMIC MODEL VERIFICATION

Presiding: S.Y. WANG, Center for Computational Hydroscience and Engineering, University of Mississippi, Oxford, MS

Numerical Model Verification by Prescribed Solution Forcing — A Test Case: D.P. OEE, Delta Hydraulics, THE NETHERLANDS, F.M. TOHO and S.Y. WANG, Center for Computational Hydroscience and Engineering, University of Mississippi, Oxford, MS

Verification Of A Three-Dimensional Modeling in Apalachicola Bay: T.S. WU, NW Florida Water Management District, Havana, FL


Computational Model Verification Test Case Using Flow Data: Y. JIA AND S.Y. WANG, Center for Computational Hydroscience and Engineering, University of Mississippi, Oxford, MS

Open Boundary Condition for Multiple Level FE Tidal Current Flow Analysis: TOSHIKO KODAMA, Sabo Kogyo Co., Ltd., Kanazawa, JAPAN, and MITSUO KANAGAWA, Chuo University, Tokyo, JAPAN

SESSION: HY-50 Ballroom E

GENERAL HYDROLOGY & HYDRAULICS


User Interface For Pipe Network Programs: ISTAN LIPPA, National Park Service, Lakewood, CO

Design of Pneumatic Diffuser System: STEVE WILHELM, C.W. DOWNER AND R.E. PRICE, USAE Waterways Experiment Station, Vicksburg, MS


SESSION: HY-56 Ballroom F

WASTE SITE REMEDIATION FOR CONTAMINATED GROUND WATER/SOILS

Presiding: RAYMOND L. MONTGOMERY, USAE Waterways Experiment Station, Vicksburg, MS

Treatment of Contaminated Groundwater Using Chemical Oxidation: M.E. ZAPPI, B.C. FLEMING and M.J. CULLINANE, JR., USAE Waterways Experiment Station, Vicksburg, MS

Removal of Extremely Low Levels of Muni­ tions In A Drinking Water Supply: R.M. BRICKA and W. SHARP, USAE Waterways Experiment Station, Vicksburg, MS

Reduced Recharge Capacity of a Pump and Treatment System: C. TEETER, D. GUNNISON, N. FRANCINGUES, and M. ZAPPI, USAE Waterways Experiment Station, Vicksburg, MS

Properties of Solidified/Stabilized Chrome­ nium Contaminated Soil: B.C. FLEMING and M. JOHN CULLINANE, JR., USAE Waterways Experiment Station, Vicksburg, MS

SESSION 9/8:15-9:45am Con't.


Atrazine Biodegradation in Biological Granulated Activated Carbon Columns: M.K. BANKS and C.C. HUANG, Kansas State University, Manhattan, KS

Effects of Pre-Oxidation on In-Line Filtra­tion: Particle and Manganese Removal: JOHN E. TOBIASON and NAGARAJU K. VINOD, University of Massachusetts, Amherst, MA

Removal of Trivalent Methane Precursors by Ferric Chloride Coagulation: ANNE STUBSTILL, Jordan, Jones, and Goulding, Atlanta, GA, and A.P. AMIRI, Institute of Technology, Atlanta, GA

SESSION: ID25 Ballroom F

HYDROLOGIC APPLICATIONS OF WATERSHED MANAGEMENT

Presiding: LARRY M. YOUNKIN, Bucknell University, Lewisburg, PA

Darcy-Weisbach Roughness Coefficients for Selected Reside Materials: JOHN E. GILLEY, EUGENE R. KUTTIWITZ and GARY A. WIEMAN, University of Nebraska, Lincoln, NE


Prediction of Sedimentation from Small Watershed in Poland in a Changing Environment: KAZIMIERZ BANASIK, Warsaw Agricultural University, Warsaw, Poland

7-Day 10-Year Flow Relationships for Ungauged Sites in Central Italy: PIERGIO Abinci and STEFANO CASADEI, University of Pordenza, Pordenza, ITALY

SESSION ID20 Chesapeake A

CURVE NUMBERS — STATUS AND DEVELOPMENT

Presiding: ALAN T. HJELMFEIT, JR., University of Missouri, Columbia, MO

Soil Moisture and Runoff — Another Look: JOSEPH A. VAN MULLEM, Soil Conservation Service, Bozeman, MT


Progress Report ARS/SCS Runoff Curve Number Work Group: DON WOODWARD, USA-SCS, Washington, DC, W.I. GROVER, USA-ARS, University Park, PA

in Defense of Curve Numbers, A Professional Quandary: R.H. HAWKINS and A.T. HJELMFEIT, University of Missouri, Columbia, MO
Case
Presiding: ARUN K. DEB, Roy F. Weston, Inc.,
West Chester, PA
Water Main Rehabilitation—Needs for the
90's: D. KELLY O'DAY, Massachusetts Water
Resources Authority, Boston, MA
A Review of Current UK Techniques for
Rehabilitating Water Mains: MIKE JONES,
Severn Trent Water Limited, Leicester, LEEDS,
UNITED KINGDOM
Costs of Rehabilitation of Water Distribution
Systems: PETER K. MAC EWEN, Chester
Water Authority, Chester, PA
Rapid Rehabilitation Techniques: STEVEN E.
COOPER and GREGORY C. HEITZMAN, Louisville
Water Company, Louisville, KY

SESSION: WR50
WATER SUPPLY AND CONSERVATION
II
Presiding: CLAIRE WELTY, Drexel University, Phila-
delphia, PA
Economic & Financial Implications of Water
Conservation in a Southeastern City:
DAVID H. MOREAU, University of North Carolina,
Raleigh, NC
Statistical Analysis of Wastewater Flow
Reduction: ROGER PUTTY and M. NAJMS
SADRI, James Montgomery, Inc, Sacramento,
CA, AND WILLIAM O. MADDUS, James Montgomery,
Inc, Walnut Creek, CA, KAYLEEN WARNER, Office
of Environmental Management, San Jose, CA
Water Conservation in the Delaware River
Basin: JEFFREY FEATHERSTONE, Delaware
River Basin Commission, West Trenton, NJ

SESSION: WR45
STORM WATER FACILITIES
Presiding: CHARLES H. CALL, Salt Lake City
Public Utilities, Salt Lake City, UT
Efficient Sizing of Stormwater Treatment
Ponds: THOMAS R. SEARS and BRENDACAN
RAVENSWAY, CH2M HILL, Orlando, FL
Retooling Storm Water Facilities for
Quantity and Quality Control: STUART G.
WALESH, Valparaiso University, Valparaiso, IN
A Storm Water Utility Case Study Salt-Lake
City, Utah: CHARLES H. CALL, Salt Lake City
Public Utilities, Salt Lake City, UT
Analytical Hydraulic Modeling of Road
Culverts: R. SALEH, Alamco County Public
Works Agency, Hayward, CA & R. HWANG, Sacra-
monto State University, Sacramento, CA

SESSION: EE12
SOLID WASTE RECYCLING
Presiding: GENE L. NEFF, Baltimore County Dep.
of Public Works, Towson, MD
The Evolution of Modern Trash-to-Energy
Technology: STEVEN G. TOMICZEWSKI and
FRANCOIS A. FERRANDO, Wheelabrator, Baltimore,
MD
Baltimore City Recycling Program—Case
History: GEORGE G. BALOG, KENNETH J.
STRONG, and ELLEN L. KOBLER, Baltimore City
Dept of Public Works, Baltimore, MD
Planning Centralized Recovery Facilities:
RENEE A. LAWVER, and JAY R. LUND, University
of California, Davis, CA
Solid Waste Management: The Service
Initiative: MOHAMED F. DEHAB and
WAYNE E. WOLDT, University of Nebraska, Lin-
coln, NE

SESSION: EE22
WATER POLLUTION-TOXICITY
REDUCTION EVALUATION
Presiding: RUSSELL S. DYKES, Roy F. Weston,
Houston, TX
Municipal Toxicty Reduction Evaluations:
Possible Approaches for Controlling Effluent
Toxicity: TIMOTHY MORRIS, and CRAIG COKER,
Engineering-Science, Fairfax, VA
Nonpolar Organics Toxicity in a Municipal
Effluent: CARLOS H. VICTORIA-RUEDA, Engineer-
ing-Science, Austin, TX
Case History: TRE at a Refinery/Chemical
Plant: CAROL L. LA BRECHE and RUSSELL S.
DYKES, Roy F. Weston, Houston, TX
State Permit Program and Toxics Individ-
ualControl Strategies: A Case Study: ALTAF
A. MEMON, Buchart Horn, York, PA
Toxicity Reduction of Petroleum Refinery
Wastewaters by Aerated Submerged Bio-
logical Filters: RADAWN MARTINEZ, JANAKY
RAMASWAMY, JOHN N. VEENESTRA MARTHA
ANNE WEINERT, and S.I. BURKS, Oklahoma State
University, Stillwater, OK
Toxicity Identification and Reduction Eval-
uation of a Metal-Finishing Wastewater
Treatment Plant: SAY ONG, GREGORY J.
SMITH, WENDY M.C. HUANG, WILLIAM H.
CLEMENT, Batelle Memorial Institute, Columbus,
OH, GEORGE M. DESEIVES, and MARY JAYKE,
Battelle Great Lakes Environmental Center,
Traverse City, MI

SESSION: ID27
WEATHER MODIFICATION AND
CLIMATE CHANGE
Presiding: DON GRIFFITH, North America.
Weather Consultants, Salt Lake City, UT
Seven Legal Strategies to Cool Global
Warming: RAY JAY DAVIS, Brigham Young Univer-
sity, Provo, UT
The Sensitivity of Streamflow and Water
Supply in the Colorado Basin to Climatic
Changes: LINDA L. NASH, Pacific Institute for
Studies in Development, Environment, and Secu-
rity, Berkeley, CA
Importance of Tropical Rainfall Measuring
Mission (TRMM) Satellite to Hydrological
Investigations: JOANNE SIMPSON, NASA/
Goddard Space Flight Center, Greenbelt, MD
The Use of Sophisticated Three-Dimen-
sional Numerical Models in Weather Modifi-
cation Efforts: T.L. CLARK, R.T. BRUNTJES,
W.D. HALL, National Center for Atmospheric Re-
search, Boulder, CO

SESSION: ID21
DISTURBED LANDS HYDROLOGY
Presiding: VICTOR HASFURTHER, University of
Wyoming, Laramie, WY
Hydrologic Considerations in Mined Land
Reclamation: PATRICK T. TYSELL, and MAR-
TIN W. STEARNS, Thunder Basin Coal Company,
Wright, WY
Variations in Curve Number for a Re-
claimed AML Site: K. JAMES FORNSTROM and
JAMES L. SMITH, University of Wyoming,
Laramie, WY
Hydrogeotechnical Considerations for the
Disposal of Oil Shale Solid Waste Material:
VICTOR R. HASFURTHER and JOHN P. TURNER,
University of Wyoming, Laramie, WY
Simulation of Runoff and Infiltration of
Disturbed Land: BEN C. YEN, University of
Illinois at Urbana-Champaign, Urbana, IL,
ROBERT RIGGINS, U.S. Army Corps of Engineers,
Construction Engineering Research Laboratory,
Champaign, IL

SESSION: ID10
Crosiers A

Crop Classification and Area Estimation
Using Multispectral Video-Radiometer Re-
 mote Sensing: R. AHMED and CHRISTOPHER
NEALE, Utah State University, Logan, UT

Hydraulics Division
Wednesday Awards Luncheon
Ballroom B
11:45 am-1:15 pm
Presiding: ADNAN ALSAFFAR, Chair, Hydraul-
ics Division