FOREWORD

The abstracts included in this volume are abstracts of papers presented during the 28th USSD Annual Meeting and Conference, held April 28 – May 2, 2008, in Portland, Oregon. Complete papers are presented on the accompanying CD.

The theme of the 28th USSD Conference was ***The Sustainability of Experience — Investing in the Human Factor***. The Conference technical program was organized by several USSD Committees under the leadership of **Douglas D. Boyer**, Federal Energy Regulatory Commission. The Theme addressed challenges facing the profession in training and transferring knowledge and judgment from soon-to-be-retiring experts to eager younger professionals who will be our future leaders.

The Conference **Technical Program** and associated Workshops on **Dam Failures/ Incidents** and on **Dam Decommissioning** provided an opportunity for dam engineers, owners, operators, environmental managers and interest groups to share and discuss best practices and new technologies in design, construction, rehabilitation, monitoring and surveillance, operation, safety, decommissioning and risk management. A total of 81 papers are included in the Proceedings. Authors include specialists with broad experience from government agencies, utilities, academia, water districts, consulting firms and private industry.

The Conference Organizing Committee extends thanks and appreciation to the Host of the 28th Annual Meeting and Conference, **Portland General Electric.**

Special thanks are also extended to the Committee Members who selected the abstracts and reviewed the technical papers, and to the authors who prepared the papers included in the Proceedings.

The Office of International Affairs, **Bureau of Reclamation**, sponsored this Abstracts Book, and this support is acknowledged with appreciation.

CONTENTS

Plenary Session

The Quest for the Baldrige 1
Ron Lemons, **Robert F. Pence** and **Cindy P. Milrany**; Freese and Nichols, Inc.

Further Insight into the Hydraulic Uplift that Led to the St. Francis Dam Collapse . . . 3
Geraldo R. Iglesia and **James L. Stiady**, G^2D Resources, LLC; and **Jeffrey A. Shoaf**, San Diego County Water Authority

Design and Construction of Deep Secant Pile Seepage Cut-off Walls Under the Arapuni Dam in New Zealand 5
Peter D. Amos, DamWatch Services Limited; **Donald A. Bruce**, Geosystems, L.P.; **Marco Lucchi**, Trevi S.p.A.; **Neil Watkins**, Mighty River Power Limited; **Nick Wharmby**, Brian Perry Civil

40 Years of Rock Anchors for Dams in North America — Lessons Learned 7
Donald A. Bruce, Geosystems, L.P.; and **John S. Wolfhope**, Freese and Nichols, Inc.

Big Tujunga Dam Seismic Rehabilitation and Spillway Modification Project 9
Vik Iso-Ahola and **Glenn Tarbox,** MWH Americas, Inc.; and **Daniel L. Wade**, San Francisco Public Utilities Commission

Granite Creek Dam — The Progressive Stability Analysis 11
Chad B. Gillan and **Guy S. Lund**, URS Corporation

Finite Element Analysis for Concrete Interface Treatment at the Hinze Dam Spillway Crest Structure Stage 3 Raise 13
Scott L. Jones, **David Hughes** and **Salvatore Todaro**, URS Corporation; and **Steve O'Brien**, Level 6

Nonlinear Incremental Thermal Stress-Strain Analysis for Portugues Dam, an RCC Gravity Arch Dam 15
Ahmed Nisar, MMI Engineering; **David Dollar**, Corps of Engineers; **Paul Jacob** and **Dongmei Chu**, MMI Engineering; **Charles Logie**, LTD Engineering**;** and **Guzhao Li**, MMI Engineering

Exploration and Geotechnical Characterization for Evaluating the Stability of Hungry Horse Dam 17
Christopher N. Powell, **Peter T. Shaffner** and **Jerry Wright**, Bureau of Reclamation

Nonlinear, 3-D, Dynamic, Coupled Dam-Foundation Analyses for Estimating Risks at Hungry Horse Dam 19
Gregg A. Scott and **Barbara L. Mills-Bria**, Bureau of Reclamation

Duckett Dam — An Ambursen Dam Evaluation 21
Guy S. Lund, URS Corporation

Risk Estimates for Seismic Failure of Spillway Gates 23
William R. Fiedler, **Ernest Hall** and **Gregg Scott**, Bureau of Reclamation

State of the Practice — Grout Enriched RCC in Dams 25
Brian A. Forbes, GHD Pty, Ltd.; **Kenneth D. Hansen** and **Thomas J. Fitzgerald**, Schnabel Engineering

Properties of Grout Enriched Roller Compacted Concrete 27
Stephen B. Tatro, **James K. Hinds** and **Jana L. West**, Corps of Engineers

Risks Associated with Deteriorating Concrete Dams 29
Larry K. Nuss, **Tim P. Dolen** and **Matt Jones**, Bureau of Reclamation

Risk

Using Risk to Make Decisions, Prioritize Resources, and Measure Performance for Water Resources Facilities at the U.S. Bureau of Reclamation 31
Nathan Snorteland and **Elizabeth Dinneen**, Bureau of Reclamation

USACE Dam Safety Program — Transition to Risk Management. 33
Eric Halpin and **Andy Harkness**, Corps of Engineers

Beyond Black and White — Risk-Informed Decision Making in a Regulatory Environment 35
Patrick J. Regan and **Douglas D. Boyer**, Federal Energy Regulatory Commission

Joint Development of a Risk Management and Assessment Strategy for Federal Dam and Levee Owners 37
Andy Harkness and **Eric Halpin**, Corps of Engineers; and **Nathan Snorteland** and **Brian Becker**, Bureau of Reclamation

Societal Risk Tolerance and Safety Guidelines — How Safe do Dams Need to Be?. . . 39
Nathan Snorteland, Bureau of Reclamation; **Douglas Boyer**, Federal Energy Regulatory Commission; and **Dan Grundvig**, Bureau of Reclamation

Consideration of Extremely Remote Loading Conditions for a Dam with High Downstream Consequences 41
Phoebe Percell and **Ernest Hall**, Bureau of Reclamation

Generalized Event Tree Algorithm and Software for Dam Safety Risk Assessment . . . 43
Anurag Srivastava, Utah State University; and **David S. Bowles** and **Sanjay S. Chauhan**, Utah State University and RAC Engineers and Economists

Potential Failure Modes (PFM) and the PFM Resource Tool 45
Justin Nettle, Federal Energy Regulatory Commission; and **Jeffrey A. Esterle**, Corps of Engineers

Screening Update for Portfolio Risk Analysis for U.S. Army Corps of Engineers Dams 47
Jeffrey T. McClenathan and **Andy Harkness**, Corps of Engineers

USACE Periodic Assessments — A Risk-Informed Inspection Program. 49
Troy S. O'Neal, Corps of Engineers

Interim Risk Reduction Measures for Dam Safety 51
Timothy M. O'Leary, Corps of Engineers

Uncertainties in Low-Probability Estimates of Seismic Hazard: Implications of a Constant Risk Goal for Dam Safety 53
Larry Anderson and **Jon Ake**, Bureau of Reclamation

Extreme Flood Probability Estimation Methods for Dam Safety Risk Analysis 55
John F. England, Jr., Bureau of Reclamation; and **Robert E. Swain**, Consulting Hydrologist/Engineer

Embankment Dams

Evaluation of Seepage and Post-Seismic Stability Concerns — Isabella Auxiliary Dam, California 57
Mike Knarr, **Elena Sossenkina** and **Scott Anderson**, Kleinfelder, Inc.; **Ronn Rose**, Corps of Engineers; **Keith Ferguson**, Kleinfelder, Inc.; and **Rick Britzman**, Corps of Engineers

Sinkhole Incident at Swinging Bridge Dam 59
David E. Capka and **Eugene Gall**, Federal Energy Regulatory Commission

Big Easy Levee Design: Proposed Improvements to the Existing 17th Street and London Avenue Canal Levees 61
Del Shannon, **John Koontz**, **Lawrence Almaleh** and **Molly O'Connor**, Black & Veatch Corporation

Long Term Pressure Relief System Performance for Dams on Permeable Foundations 63
Robert L. Arnold, Corps of Engineers

Control of Hydrofracturing at Lake Fort Smith Dam 65
Christopher Groves and **Mike Lambert,** Shannon & Wilson

Where Clay Meets Sand: Comparing a Simple Filter Simulation with Filter Tests . . . 67
Christopher Hill, Metropolitan Water District of Southern California

Seepage Analysis and Initial Performance of the Big Sand Wash Reservoir Enlargement 69
Jaco Esterhuizen, **Mike Mickelson** and **Nason J. McCullough**, CH2M Hill, Inc.; and **Lee Wimmer**, Central Utah Water Conservancy District

Influence of VerticaLeveesl Shaking on Embankment Dam Seismic Response 71
Gilles Bureau and **William A. Rettberg**, GEI Consultants, Inc.; and **Jacob Eymann**, El Dorado Irrigation District

Methods to Evaluate Seismic Risks for Embankment Dams 73
Karl Dise and **Nathan Snorteland**, Bureau of Reclamation

Simplified Estimation of Seismic Deformation for Risk Analysis 75
Thomas G. Pace, Stantec Consulting Services, Inc.; **Jeffrey A. Schaefer** and **Timothy M. O'Leary**, Corps of Engineers; and **Alan F. Rauch**, Stantec Consulting Services, Inc.

Seismic Remediation of Embankment Dams — Accepting Upstream Slope Failure. . . 77
Steve Collins and **Kellie Marshall**, Federal Energy Regulatory Commission

Concrete Walls and Grout Curtains in the Twenty-First Century: The Concept of Composite Cut-offs for Seepage Control 79
Donald A. Bruce, Geosystems, L.P.; **Trent L. Dreese***,* Gannett Fleming, Inc.; and **Douglas M. Heenan***,* Advanced Construction Techniques Ltd.

Risk-Based Decisions and Design for Seismic Dam Safety Modifications. 81
Dennis L. Hanneman and **David R. Gillette**, Bureau of Reclamation

The Influence of the Culvert on the Leakage at Lower Carno Dam 83
Jane Walbancke, **Andrew Rowland** and **Lucy Mistry,** Black & Veatch

Failure of Swift No. 2 Forebay Dam 85
Patrick J. Regan, Federal Energy Regulatory Commission; **Gary Huhta**, Public Utility District No. 1 of Cowlitz County; and **William N. Lagnion**, Federal Energy Regulatory Commission

Swift No. 2 Hydroelectric Project Reconstruction — Features and Procedures Adopted to Mitigate Dam Safety Risks 87
Thomas J. O'Brien, **Steve Benson** and **Mike Pavone**, Washington Division of URS Corporation

Geotechnical Foundation Considerations for the Reconstruction of the Swift No. 2 Power Canal, WA. 89
Sarah Wilkinson Kemp and **Stephen A. Benson**, URS Corporation, Washington Division

Emergency Remedial Actions at A.V. Watkins Dam 91
Bruce C. Barrett and **Mark Bliss**, Bureau of Reclamation

Lake Needwood Dam Forensic Evaluation and Rehabilitation 93
Bob Pinciotti, URS Corporation; **Greg Zamensky,** Black & Veatch Corporation; and **Andy Frank**, Maryland-National Capital Parks and Planning Commission

A Case History of a Major Seepage and Internal Erosion Event at East Branch Dam, Elk County, Pennsylvania 95
Brian H. Greene and **James E. Sekela**, Corps of Engineers

Hydraulics and Hydrology

Use of NEXRAD Weather Radar Data with the Storm Precipitation Analysis System (SPAS) to Provide High Spatial Resolution Rainfall Analyses for Runoff Model Calibration and Validation 97
Edward M. Tomlinson, Applied Weather Associates LLC; **Tye W. Parzybok** and **Douglas M. Hultstrand**, Metstat, Inc; and **William D. Kappel**, Applied Weather Associates LLC

Analysis of Namgang Dam Flood Control During Intensive Rainfall in 2006 99
Woo-Gu Kim, **Jin-Hyeog Park** and **Eul-Rae Lee**, Korea Water Resources Corporation

New PMP Temporal Distributions and a Simplified Breach Method for Dams in Texas 101
John L. Rutledge, Freese and Nichols, Inc.; and **Warren Samuelson**, Texas Commission on Environmental Quality

FERC Dam Security Program Update 103
Frank Calcagno, Federal Energy Regulatory Commission

HR BREACH: Developing a Practical Breach Model to Meet Industry Needs 105
Mark Morris and **Mohamed Hassan**, HR Wallingford Ltd.; **Yves Buchholzer**, École Centrale de Lyon; and **Tom Davies**, Wallingford Software Inc., US

Development of Next-Generation Embankment Dam Breach Models 107
Tony L. Wahl, Bureau of Reclamation; **Gregory J. Hanson**, USDA-ARS; **Jean-Robert Courivaud**, Electricité de France; **Mark W. Morris**, HR Wallingford; **René Kahawita**, École Polytechnique de Montréal; and **Jeffrey T. McClenathan** and **D. Michael Gee**, Corps of Engineers

Results from Overwash Testing on Earthfill Embankments in South Florida 109
Bruce A. Phillips and **Becky J. Hachenburg**, MWH Americas, Inc.; and **Jeffrey R. Kivett**, South Florida Water Management District

Practical Application of Research Related to High Velocity Flows Over Open Offset Joints in Spillways 111
John Trojanowski, Bureau of Reclamation

A Labyrinth Rises in the Heart of Texas 113
Victor M. Vasquez, **M. Leslie Boyd** and **John S. Wolfhope**, Freese and Nichols, Inc.;and **Ricky Garrett,** City of Waco

Evaluation of Existing Dams for Overtopping Failure Mode Based on Risk Considerations 115
William R. Fiedler, John F. England, Jr., and **John H. LaBoon**, Bureau of Reclamation

Construction

Multi-Year Water Resources Project 117
Nathan Snorteland and **Daniel Maag**, Bureau of Reclamation

Alternative Project Delivery Methods for Dam Construction and Rehabilitation . . . 119
Daniel J. Hertel, Barnard Construction Company, Inc.; **Daniel L. Johnson**, GEI Consultants, Inc.; **William F. Fiedler,** Bureau of Reclamation; and **Dietmar Scheel**, MWH Americas, Inc.

Lessons Learned from Construction of Prototype Embankment Dams in South Florida 121
Gregory A. Hillebrenner and **Bruce A. Phillips**, MWH Americas, Inc.; and **Jeffrey R. Kivett**, South Florida Water Management District

Geotextiles in Dams — Forging Federal Guidelines 123
Douglas A. Crum, Corps of Engineers

White River Project, Dike 14/15 Backflow Prevention Structure. 125
Steve Benson and **Rahim Nasserziayee**, URS Corporation, Washington Division; and **Frank Hella**, Puget Sound Energy

Performance of the Ralston Dam Spillway 127
Gokhan Inci, URS Corporation; and **Michael J. Miller**, Denver Water

Spillway Gate Isolation Using Segmental Floating Bulkheads 129
Frederick Lux, Schnabel Engineering South, LLC

Surveillance and Monitoring

Detecting Voids Behind Conduits Using Acoustic Technology 131
Fred A. Travers and **William F. Kepler**, Bureau of Reclamation

Maganging Dam Safety Ricks through Surveillance and Monitoring Plans and Surveillance and Monitoring Reports 133
Patrick J. Regan, **Justin D. Nettle** and **John Zygaj**, Federal Energy Regulatory Commission

Pumped Storage Technical Guidance 135
Warren Witt, Ameren UE; **Ernest D. Brockman, Jr.**, Duke Energy; and **David W. Lord**, Federal Energy Regulatory Commission

Geotechnical Analysis and Instrumentation Monitoring During the Draw-Down and Rewatering of the Blenheim-Gilboa Pumped Storage Power Project 137
Chad W. Cox, GZA GeoEnvironmental, Inc.; **Fan Xi,** New York Power Authority; **Alton P. Davis, Jr.**, Consultant; **Robert Knowlton**, New York Power Authority; and **William H. Hover**, GZA GeoEnvironmental, Inc.

Providing Improved Dam Safety Monitoring Using Existing Staff Resources: Fern Ridge Dam Case Study 139
Barry K. Myers, Engineered Monitoring Solutions; and **David H. Scofield**, Corps of Engineers

Seepage Analysis at Wolf Creek Dam: Studying the Diagnostic Effectiveness of Audio Frequency Domain Magnetics in Karst Environments 141
Val Kofoed and **Paul Rollins**, Willowstick Technologies, LLC

Seepage and Piping Toolbox

Seepage and Piping Toolbox Overview 143
John Cyganiewicz, Bureau of Reclamation; **George Sills**, Corps of Engineers; **Robin Fell**, University of New South Wales; **Richard Davidson**, URS Corporation; **Mark Foster,** URS Australia Pty Ltd.; **Noah Vroman**, Corps of Engineers

Seepage and Piping Toolbox — Initiation of Internal Erosion 145
Robin Fell, University of New South Wales; **Mark Foster**, URS Australia Pty Ltd.; **Richard Davidson**, URS Corporation; **John Cyganiewicz**, Bureau of Reclamation; **George Sills**, Corps of Engineers; and **Noah Vroman**, Corps of Engineers

Seepage and Piping Toolbox — Continuation, Progression, Intervention and Breach 147
Mark Foster, URS Australia Pty Ltd.; **Robin Fell**, University of New South Wales; **Noah Vroman**, Corps of Engineers; **John Cyganiewicz**, Bureau of Reclamation; **George Sills**, Corps of Engineers; and **Richard Davidson**, URS Corporation

Seepage and Piping Toolbox — Beta Trial Case Histories 149
Noah Vroman, Corps of Engineers; **John Cyganiewicz**, Bureau of Reclamation; **George Sills**, Corps of Engineers; **Robin Fell**, University of New South Wales; **Richard Davidson**, URS Corporation; and **Mark Foster,** URS Australia Pty Ltd.

Environmental/Water Resources

Water Storage — an Environmental Necessity? 151
Blaine N. Dwyer, Boyle Engineering Corporation

Re-Operation of Multi-Purpose Reservoirs for Economic and Environmental Benefits 153
Felix Froehlich, Technical University of Darmstadt; **Robert Dittmann**, Technical University of Dresden; **Dirk Muschalla** and **Manfred Ostrowski**, Technical University of Darmstadt; and **Reinhard Pohl**, Technical University of Dresden

Water Resources Capital Improvements in a Post-Conflict Environment: The Iraq Experience. 155
Azad Mohammadi, Azad Engineering, Inc.; and **Hassan Janabi**, Stanley Baker Hill, LLC

Dam Decommissioning

Marmot Dam Removal 157
J. W. Sager and **M. R. Meyer**, Cornforth Consultants, Inc.; and **T. Keller**, Portland General Electric Company

Removal of Savage Rapids Diversion Dam — Part One 159
Richard D. Benik, Bureau of Reclamation

A Chiloquin Romance — Restoring the Sprague River 161
Thomas E. Hepler, Bureau of Reclamation

Poster Session

Evaluating Drains in a Risk-Based Context 163
Bill Fiedler, **Gregg Scott** and **Lloyd Crutchfield**, Bureau of Reclamation

Laboratory Studies of High Velocity Flows Over Open Offset Joints 165
K. Warren Frizell, Bureau of Reclamation

Structural Evaluation and Rehabilitation of Montgomery Dam Lift Gates. 167
William A. Karaffa and **Paul A. Surace**, Corps of Engineers

GIS-Based Soil Erosion Modeling with Climate Change Scenario in Imha Dam Basin, Korea 169
Geun-Sang Lee, **Kyung-taek Yum** and **Deuk-koo Koh**, Korea Water Resources Corporation

Enhancement Program for Hydrologic Safety of Existing Dams in Korea. 171
Hyun Lee, **Deuk-koo Koh** and **Kyung-taek Yum** Korea Water Resources Corporation

Evaluation of Proposed Campus Construction on Existing Levee — New TCCD Downtown Campus, Fort Worth, Texas. 173
Marc T. Miller, **Elena Sossenkina**, **Jie Yu** and **Mike Shiflett**, Kleinfelder, Inc.

Deep Grout Curtain Cutoff for Large Storage Reservoirs in Rock 175
Faruk Oksuz and **Cary Hirner**, Black & Veatch Corporation

Evaluation of Risk for a New Design at the Conceptual Level 177
Phoebe Percell and **Bill Fiedler**, Bureau of Reclamation; **Rick Poeppelman**, Corps of Engineers; and **Ernie Hall**, Bureau of Reclamation

Investigation and Evaluation on the Safety of Soyanggang Dam Auxiliary Spillway Tunnel along Large Fault Zones 179
Young-Kwon You, **Yang-Soo Yoo** and **Kyung-Taek Yum**, Korea Water Resources Corporation; **Moo-Young Song**, Chungnam National University, **Sung-Hun Kwak**, Samsung; and **Young-Wan Shin**, Hakyong Engineering Company

NOTES

THE QUEST FOR THE BALDRIGE

Ron Lemons[1]
Robert F. Pence[2]
Cindy P. Milrany[3]

ABSTRACT

The President of the United States presents the Malcolm Baldrige National Quality Award to organizations that are judged to be outstanding in seven areas: leadership; strategic planning; customer and market focus; measurement, analysis, and knowledge management; workforce focus; process management; and results. Most states have a state award based on the Baldrige Criteria. Freese and Nichols participated in the Texas program in 2006 and 2007 and plans to participate in the national Baldrige program in 2009. We have used our quest for the Baldrige Award to drive investment in our employees, to sustain our experience and to prepare the firm for our next 100 years. This paper describes our quest, what we have accomplished so far and what we have learned. Our experience is directly applicable to any public or private organization that is striving to improve and sustain its performance.

[1] Senior Vice President and Chief Operating Officer, Freese and Nichols, Inc., Ft. Worth, Texas, RML@freese.com
[2] President and Chief Executive Officer, Freese and Nichols, Inc., Fort Worth, Texas, RFP@freese.com
[3] Senior Vice President and Chief Financial Officer, Lead FNI's Baldrige Initiative, Freese and Nichols, Inc., Fort Worth, Texas, CPM@freese.com

NOTES

FURTHER INSIGHT INTO THE HYDRAULIC UPLIFT THAT LED TO THE ST. FRANCIS DAM COLLAPSE

Geraldo R. Iglesia, Ph.D., P.E./G.E.[4]
James L. Stiady, Ph.D., P.E.[5]
Jeffrey A. Shoaf, P.E.[6]

ABSTRACT

Several decades past the catastrophic collapse of the ~200-foot-high St. Francis Dam in March 1928, valuable lessons can still be mined from this humbling experience that has been considered as the deadliest American civil engineering failure of the 20th century. Numerous subsequent investigations of the failure of St. Francis Dam, located about 35 miles northwest of downtown Los Angeles (California), have pointed to the inadequate foundation of the curved concrete gravity dam as the main culprit. Moreover, there appeared to be serious deficiencies in the understanding of dam engineering principles at that time, especially pertaining to hydraulic uplift pressures at the base and within the body of the dam itself. Through the application of modern computer-aided finite-element modeling of the probable seepage patterns in the vicinity of the St. Francis Dam around the time when it failed, this paper provides additional insight into the major underlying causes of the dam collapse. Results of structural stability analyses (considered conventional per present-day standards) of cross-sections of the dam, corresponding to various stations along its length, are then presented in a manner that depicts plausible mechanisms of the collapse of St. Francis Dam – a unique showcase from which dam engineering practitioners can learn priceless lessons for potential application on similar projects.

[4] Principal, G²D Resources, LLC, 7966 Arjons Drive, Suite 204, San Diego, California 92126-6361. griglesia@g2dresources.com.
[5] Senior Engineer, G²D Resources, LLC, 7966 Arjons Drive, Suite 204, San Diego, California 92126-6361. jlstiady@g2dresources.com.
[6] Principal Engineer, San Diego County Water Authority, 4677 Overland Avenue, San Diego, California 92123-1233. jshoaf@sdcwa.org.

NOTES

DESIGN AND CONSTRUCTION OF DEEP SECANT PILE SEEPAGE CUT-OFF WALLS UNDER THE ARAPUNI DAM IN NEW ZEALAND

Peter D Amos[7]
Donald A. Bruce[8]
Marco Lucchi[9]
Neil Watkins[10]
Nick Wharmby[11]

ABSTRACT

Arapuni Dam was completed in 1927 and is a 64m high curved concrete gravity structure across the Waikato River in New Zealand. A series of foundation leakage events related to piping and erosion of clay infill within joints in the rock foundation have occurred since the dam was built. Leakage was evidenced by increased drainage flows and uplift pressures.

The paper describes the design and construction features of the deep seepage cutoff walls that have recently been completed to control piping and erosion in the foundation. These include:

- selection and development of the cutoff wall solution
- construction through an existing dam
- construction with a full reservoir and the systems used to manage this risk
- assuring continuity in a 400mm diameter 90m deep secant pile wall

With few precedents for this type of work and none constructed in weak rock and to 90 m depth, the Arapuni Dam seepage cutoff project significantly extends international small diameter overlapping/secant pile technology and experience.

[7] Principal Engineer, DamWatch Services Limited, Wellington, New Zealand; peter.Amos@DamWatch.co.nz
[8] President, Geosystems, L.P., Venetia, PA 15367, U.S.A.
[9] Project Manager, Trevi S.p.A.. Via Dismano, 5819, 47023 Cesena, Italy
[10] Project Manager, Mighty River Power Limited, Hamilton, New Zealand
[11] Engineering Manager, Brian Perry Civil, Hamilton, New Zealand

NOTES

40 YEARS OF ROCK ANCHORS FOR DAMS IN NORTH AMERICA — LESSONS LEARNED

Dr. Donald A. Bruce[12]
John S. Wolfhope, P.E.[13]

ABSTRACT

Over the last few years, the authors have acted as Co-Principal Investigators on a National Research Program on Rock Anchors for Dams. Three main tasks have been accomplished, leading to the development of a comprehensive database:

(i) comparative analysis of the five successive sets of "recommendations" governing practice (1974-2004);
(ii) compilation of over 230 technical papers describing North American case histories; and
(iii) development of details of over 400 projects executed on North American dams.

As a result, the authors are able now to provide a historical perspective to the art and science as it has evolved over the years. Technical guidance is provided on the key areas of design, corrosion protection, and construction practices. Cost information is also supplied as a first stage in project cost estimation.

[12]President, Geosystems, L.P., P.O. Box 237, Venetia, PA 15367, U.S.A.; Phone: (724) 942-0570; Fax: (724) 942-1911; Email: dabruce@geosystemsbruce.com.
[13] Principal, Freese and Nichols, Inc., 10814 Jollyville Road, Building 4, Suite 100, Austin, TX 78759-5674, U.S.A.; Phone: (512) 617-3118; Fax: (512) 451-7956; Email: jsw@freese.com.

NOTES

BIG TUJUNGA DAM SEISMIC REHABILITATION AND SPILLWAY MODIFICATION PROJECT

Vik Iso-Ahola, P.E. [14]
Glenn Tarbox, P.E.[15]
Daniel L. Wade, P.E., G.E.[16]

ABSTRACT

The Big Tujunga Dam, owned and operated by the Los Angeles County Department of Public Works (LACDPW), is a variable radius thin arch dam. For approximately 30 years, the reservoir operating level has been restricted to an elevation that results in a storage capacity reduction of 75% by order of the California Department of Water Resources, Division of Safety of Dams (DSOD) due to seismic stability concerns. In addition, the spillway capacity does not meet DSOD standards for passing the Probable Maximum Flood (PMF).

In recent years, LACDPW commissioned MWH Americas, Inc. (MWH) to embark on studies to re-analyze both the seismic and hydraulic issues related to the dam. LACDPW elected to incorporate a complete rehabilitation of the dam into the final design for the structural and hydraulic rehabilitation including geotechnical, structural, hydraulic, mechanical and electrical rehabilitation.

This paper briefly reviews the history of the dam, discusses the purpose of the dam rehabilitation and benefits, highlights aspects of the innovative design, and address project financing including securing grants for the approximately $90M project. Construction commenced in Fall 2007 and is expected to take approximately three years.

[14] Project Manager, MWH Americas, Inc., 2121 N. California Blvd, Suite 600, Walnut Creek, CA 94596, vik.iso-ahola@mwhglobal.coms
[15] Vice President, MWH Americas, Inc., 2353 130th Avenue N.E., Suite 200, Bellevue, WA 98005, glenn.tarbox@mwhglobal.com
[16] Project Manager, San Francisco Public Utilities Commission, 1145 Market Street, 3rd Floor, San Francisco, CA 94103, dwade@sfwater.org

NOTES

GRANITE CREEK DAM — THE PROGRESSIVE STABILITY ANALYSIS

Chad B. Gillan, PE [17]
Guy S. Lund, PE [18]

ABSTRACT

URS Corporation recently preformed a comprehensive structural stability analysis of Granite Creek Dam, a concrete-arch dam located in Prescott, Arizona. The analysis used both linear and non-linear finite element models (FEMs) to simulate the structural behavior of the dam and evaluated the behavior due to usual, unusual, and extreme loads. This paper discusses the basics to the analysis and presents a method to evaluate the stability of the dam at the dam/foundation interface, called progressive stability analysis (PSA).

[17] Civil/Structural Engineer, URS Corporation, 8181 E. Tufts Ave. Denver, Colorado 80237 chad_gillan@urscorp.com
[18] Principal Civil/Structural Engineer, URS Corporation, 8181 E. Tufts Ave. Denver, Colorado 80237 guy_lund@urscorp.com

NOTES

FINITE ELEMENT ANALYSIS FOR CONCRETE INTERFACE TREATMENT AT THE HINZE DAM SPILLWAY CREST STRUCTURE STAGE 3 RAISE

Scott L. Jones, P.E.[19]
David Hughes, P.E.[20]
Salvatore Todaro, P.E.[21]
Steve O'Brien[22]

ABSTRACT

As a part of a 14.75 metre raise of the Hinze Dam, a central core rockfill dam owned by the Gold Coast County Council in Queensland, Australia, the existing 33 m high mass concrete spillway structure is being raised by approximately 12.5 meters. The water supply reservoir will remain in operation throughout construction. As part of the design of the concrete overlay used for the spillway raise, URS undertook a series of finite element thermal and structural analyses. These were used to evaluate the effects of temperature differentials between the new and existing concrete to establish pre- and post-cooling requirements for the concrete and to evaluate the concrete mix design and the proposed construction sequence. The analyses were performed in two stages. The first was a thermal analysis to determine the distribution and magnitudes of temperatures within the composite structure in the weeks and months following placement of the overlay. A structural analysis was then performed to assess the stresses within the spillway due to both the weight of the additional concrete and changes in internal temperatures. Of particular interest was the state of stress along the interface between the old and new concrete. The results from the finite element analyses of the construction loading conditions were used to develop a testing program for the concrete mix design and to design pre- and post-cooling operations for the concrete. This paper presents the assumptions, methods, and criteria used in the analyses; the results and conclusions drawn from the analyses; and discussion on how the analyses were used to support construction of the mass concrete overlay.

[19] Civil/Structural Engineer, URS, 8181 E. Tufts Ave., Denver, CO 80237; scott_jones@urscorp.com
[20] Senior Civil Engineer, URS, 1333 Broadway, Ste 800, Oakland, CA 94612; david_hughes@urscorp.com
[21] Principal Civil Engineer, 8181 E. Tufts Ave., Denver, CO 80237; salvatore_todaro@urscorp.com
[22] Structural Engineer, Level 6, 1 Southbank Boulevard, Southbank, Melbourne, VIC 3006, Australia, steven_obrien@urscorp.com

NOTES

NONLINEAR INCREMENTAL THERMAL STRESS-STRAIN ANALYSIS FOR PORTUGUES DAM, AN RCC GRAVITY ARCH DAM

Ahmed Nisar[23]
David Dollar[24]
Paul Jacob[25]
Dongmei Chu[26]
Charles Logie[27]
Guzhao Li[28]

ABSTRACT

A nonlinear incremental thermal stress-strain analysis (NISA) was conducted to evaluate the behavior of the Portugues Dam. The purpose of the analysis was to study the effect of thermal loading caused by heat of hydration and assess the potential for cracking. The Portugues dam is designed by the U.S. Army Corps of Engineers as a roller compacted concrete (RCC) gravity arch dam, located in Ponce, Puerto Rico. At the maximum cross section, the dam is 220 feet high with a base width of 111 feet. The crest arc length for the dam is approximately 1,230 feet.

The results of the analyses are used to guide design decisions regarding initial placement temperature, location and width of contraction joints, delay time for flood pool storage, use of grouted or un-grouted joints and timing of contraction joint grouting for the grouted option. The analysis considered variables such as construction sequence, heat of hydration of concrete, volumetric changes due to creep and shrinkage and environmental factors such as heat loss or gain due to solar radiation, daily and seasonal variation of atmospheric temperature and heat loss into the foundation.

The study employed several two dimensional (2D) and three dimensional (3D) finite element models, for both thermal and stress analysis, and simplified analyses to estimate the dam's final stable temperature distribution, time required to reach the final stable temperature, potential for longitudinal and transverse cracking, temperature time histories during construction, spacing of contraction joints and contraction joint opening. Sensitivity studies were performed using different placement temperatures and variations in material properties.

[23]MMI Engineering, 475 14th Street Suite 400, Oakland, CA 94612 anisar@mmiengineering.com
[24]Department of the Army, Engineering Division, Technical Services Branch, Jacksonville District Corps of Engineers, 701 San Marco Boulevard, Jacksonville, FL 32207 David.A.Dollar@saj02.usace.army.mil
[25]MMI Engineering, 11490 Westheimer Road, Suite 150, Houston, TX 77077 pjacob@mmiengineering.com
[26]MMI Engineering, 11490 Westheimer Road, Suite 150, Houston, TX 77077 dchu@mmiengineering.com
[27]LTD Engineering, 1050 Northgate Drive, Suite 315, San Rafael, CA 94903 cvlogie@ltdengineering.com
[28]MMI Engineering, 11490 Westheimer Road, Suite 150, Houston, TX 77077 gli@mmiengineering.com

NOTES

EXPLORATION AND GEOTECHNICAL CHARACTERIZATION FOR EVALUATING THE STABILITY OF HUNGRY HORSE DAM

Christopher N. Powell[29]
Peter T. Shaffner[30]
Jerry Wright[31]

ABSTRACT

Hungry Horse Dam is a 564-foot-high concrete gravity arch dam located in northwestern Montana near Glacier National Park. Great attention was paid to the geology of the foundation during original construction in the early 1950's, but little was understood in this time period regarding potential failure modes related to sliding of foundation rock blocks. The entire left half of the dam is founded on a 30-degree dip slope in the dolomitic limestone foundation rock, with parallel bedding plane partings at various depths that daylight just downstream of the dam. Five high-angle upstream-downstream oriented faults divide the left abutment into a series of foundation blocks. Block isolation is completed by an interconnected system of the prominent high-angle joint sets in the vicinity of the upstream foundation contact. Rigid block "Newmark-type" analyses of the foundation indicated significant displacement. Therefore, a non-linear coupled analysis was initiated. To support this effort, an extensive exploration program and rigorous evaluation of the geotechnical parameters that have a direct effect on the coupled analysis results was undertaken. This paper describes that work.

[29] Geotechnical Engineer, Bureau of Reclamation, P.O. Box 25007, 86-68312, Denver, CO 80225, cpowell@do.usbr.gov
[30] Engineering Geologist, Bureau of Reclamation, P.O. Box 25007, 86-68320, Denver, CO 80225, pshaffner@do.usbr.gov
[31] Supervisory Geophysicist, Bureau of Reclamation, P.O. Box 25007, 86-68330, Denver, CO 80225, jwright@do.usbr.gov

NOTES

NONLINEAR, 3-D, DYNAMIC, COUPLED DAM-FOUNDATION ANALYSES FOR ESTIMATING RISKS AT HUNGRY HORSE DAM

Gregg A. Scott, P.E.[32]
Barbara L. Mills-Bria, P.E.[33]

ABSTRACT

Hungry Horse Dam is a concrete gravity-arch structure over 560 feet high located in northwest Montana near Glacier National Park. The dam was constructed at a time when sliding of potential foundation blocks was not recognized as a significant potential failure mode. However, the left abutment of the dam was founded entirely on a dip slope in the dolomitic limestone foundation rock, with bedding plane partings dipping approximately toward the river and daylighting in the canyon slopes downstream. Several faults and joint sets isolate rock blocks within the abutment. Uncoupled foundation analyses indicated significant block displacement under seismic loading, resulting in high estimated risks. Coupled dam-foundation finite element analyses were undertaken to refine the estimates of block displacement. Due to the complexity of these types of analyses, significant time and effort was spent calibrating and verifying the numerical model. The coupled analyses predicted much smaller displacements than the uncoupled analyses, resulting in much lower risk estimates.

[32] Civil Engineer, Senior Technical Specialist, Bureau of Reclamation, P.O. Box 25007, 86-68312, Denver, CO 80225, gscott@do.usbr.gov
[33] Civil Engineer, Principal Designer, Bureau of Reclamation, P.O. Box 25007, 86-68110, Denver, CO 80225, bmills@do.usbr.gov

NOTES

DUCKETT DAM
AN AMBURSEN DAM EVALUATION

Guy S. Lund, P.E[34]

ABSTRACT

The Washington Suburban Sanitary Commission (WSSC) supplies water and wastewater service to over 1.6 million customers in Montgomery and Prince George's counties, Maryland. An important component of the water supply system is the T. Howard Duckett (Duckett) Dam, which creates Rocky Gorge Reservoir. As with many dams, the current estimate of the probable maximum flood (PMF) for the dam is significantly greater than the flood event used during the initial design of the project. Therefore, the WSSC requested that a comprehensive dam safety assessment be performed, consisting of updating the hydrologic analysis to estimate the PMF event, performing structural analysis, and developing corrective action alternatives as necessary.

The Duckett Dam is a concrete slab and buttress type dam. The structural evaluation of the dam focused on assessing the capacity of the dam with respect to the potential failure modes (PFMs) typical for these types of structures. The PFMs for Duckett Dam were grouped into three categories: structural capacity of the reinforced concrete, sliding stability of the dam, and rock scour (erosion) due to overtopping.

This paper discusses the following topics related to the structural safety assessment for Duckett Dam:

- The most significant failure modes for this type of structure.
- Evaluation criteria used to address the identified failure modes.
- The techniques used to evaluate the behavior of the structure, which included both spreadsheet (hand) computations and a three-dimensional (3-D) finite element model (FEM). With the availability of today's computational tools, it is easy for engineers to be drawn into very complicated, non-linear analyses when evaluating complex structures like Duckett Dam. However, these studies used simple hand computations (performed by spreadsheet) and a more simplified linear elastic finite element analysis to simulate and evaluate the behavior of the dam.

[34] Principal Civil/Structural Engineer, URS Corporation, 8181 E. Tufts Ave. Denver, Colorado 80237 guy_lund@urscorp.com

NOTES

RISK ESTIMATES FOR SEISMIC FAILURE OF SPILLWAY GATES

William R. Fiedler, PE[35]
Ernest Hall, PE[36]
Gregg Scott, PE[37]

ABSTRACT

Risk analyses for dams often need to consider the potential failure of multiple features. For gated spillways, this often involves evaluating the potential failure of multiple gates and piers. For cases such as these, the failure mode may be manifested in a variety of outcomes, ranging from failure of a single feature to failure of all features. Statistical methods can be used to estimate the probability of various outcomes and to arrive at an overall probability of failure. The consequences that result from a given failure mode will also be a function of the outcome achieved and the same statistical framework can be used to estimate total risk (annualized loss of life) for a failure mode involving multiple features. A detailed example involving the seismic failure of spillway gates will be used to illustrate how failure of multiple features have been considered in risk analyses.

[35] William R. Fiedler, Civil Engineer, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, bfiedler@do.usbr.gov
[36] Ernest Hall, Civil Engineer, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, ehall@do.usbr.gov
[37] Gregg Scott, Geotechnical Engineer, Bureau of Reclamation, PO Box 25007, 86-68312, Denver, CO 80225, gscott@do.usbr.gov

NOTES

STATE OF THE PRACTICE — GROUT ENRICHED RCC IN DAMS

Brian A. Forbes, C.P.Eng.[38]
Kenneth D. Hansen, P.E.[39]
Thomas J. Fitzgerald, P.E.[40]

ABSTRACT

Grout Enriched Roller-Compacted Concrete (GERCC) is a relatively new development in the design and construction of RCC dams. GERCC is basically a method for producing a mixed-in-place conventional concrete by adding grout to uncompacted RCC and vibrating the two materials together. It was initially developed in China and has seen considerable acceptance in other countries. However, acceptance in the United States has been slow.

This paper presents the history and development of GERCC worldwide to include its limited use on RCC dams in the US. Three case studies are presented to illustrate the construction method and results. The current state of the practice with respect to RCC and grout mixture proportions, equipment used, production methods, and quality control are discussed and evaluated. Performance and properties of RCC faces as well as concerns with freeze-thaw durability and waterstop embedment are presented. Research needs and future developments are also discussed.

[38] Brian A. Forbes, P.E., Manager Major Dams Projects, GHD Pty, Ltd., 201 Charlotte Street, Brisbane Qld 4000, Australia, Phone +61 7 3316 3601; Fax +61 7 3316 3333; Email: bforbes@ghd.com.au
[39] Kenneth D. Hansen, P.E., Senior Consultant, Schnabel Engineering, 2280 South Xanadu Way, Suite 250, Aurora, CO 80014, Phone (303) 695-6500; Fax (303) 695-6239; Email: khansen@schnabel-eng.com
[40] Thomas J. Fitzgerald, P.E., Associate Engineer, Schnabel Engineering, 11A Oak Branch Drive, Greensboro, NC 27407, Phone (336) 274-9456; Fax (336) 274-9486; Email: tfitzgerald@schnabel-eng.com

NOTES

PROPERTIES OF GROUT ENRICHED ROLLER COMPACTED CONCRETE

Stephen B. Tatro, P.E[41]
James K. Hinds, PE[42]
Jana L. West, PE[43]

ABSTRACT

Grout enriched roller compacted concrete (GERCC) has gained acceptance for constructing vertical and sloped facings for RCC dams, abutment contacts, interior encasements, and other features that previously used conventional concrete. Compared to the concurrent production and placement of conventional concrete for these applications, GERCC provides an economical and less intrusive process resulting in minimal impact to RCC production operations. An investigation was done to evaluate the properties and performance characteristics of various factors of GERCC. Various properties of grout and methods of mixing were investigated including materials and mixing methods for grout and RCC, grout dosages, grout locations, and compaction variations were examined. This paper summarizes the GERCC field evaluations, reports the significant results, and provides conclusions and recommendations for GERCC use.

[41] Civil Engineer and Concrete Materials Specialist, U.S. Army Corps of Engineers, 201 North Third Street, Walla Walla, WA 99362 (509) 527-7620, fax (509) 527-7811, stephen.b.tatro@usace.army.mil
[42] Civil Engineer and Concrete Materials Specialist, U.S. Army Corps of Engineers, 333 SW 1st Avenue Portland, Oregon 97204, (503) 808-4846, fax (503) 808-4845, james.k.hinds@usace.army.mil
[43] Civil Engineer, U.S. Army Corps of Engineers, 201 North Third Street, Walla Walla, WA 99362 (509) 527-7620, fax (509) 527-7811, jana.l.west@usace.army.mil

NOTES

RISKS ASSOCIATED WITH DETERIORATING CONCRETE DAMS

Larry K. Nuss, P.E.[44]
Tim P. Dolen, P.E.[45]
Matt Jones[46]

ABSTRACT

Some of the concrete in the Bureau of Reclamation inventory of dams and appurtenant structures are deteriorating from alkali-aggregate reaction and freeze-thaw damage. The deterioration may progress to the level that renders the structures unusable and requires replacement. It is useful to estimate the remaining serviceable life of the structure because of the long lead times required for planning, funding, design, and authorization. This paper presents the field studies, monitoring, structural analyses, and risk analyses performed for Warm Springs Dam to determine the rate of deterioration, the allowable amount of deterioration before the structure becomes unusable, and the current dam safety decisions. Warm Springs Dam is a thin arch dam experiencing freeze-thaw damage. The dam was built in 1919, has a structural height of 106 feet, a crest width of 8 feet, and a base width of 34 feet. Portions of the downstream face have deteriorated up to 18-inches deep and there is an unbonded lift line at half-height. Investigations included laboratory tests on extracted 6-inch-diameter concrete cores, 2- and 3-dimensional static and seismic finite element analyses, photogrammetry surveys of the downstream face, embedded thermisters to determine the depth of freezing in the concrete, and team risk analyses.

[44] Senior Structural Engineer, Bureau of Reclamation, P.O. Box 25007, 86-68110, Denver, Colorado, 80225, 303-445-3231, Fax: 303-445-6489, lnuss@do.usbr.gov.
[45] Ibid: Senior Materials Engineer, 86-68180, 303-445-2380, 303-445-6341, tdolen@do.usbr.gov.
[46] Ibid: Geologist, 86-68320, 303-445-3198, 303-445-6478, mjones@do.usbr.gov.

NOTES

USING RISK TO MAKE DECISIONS, PRIORITIZE RESOURCES, AND MEASURE PERFORMANCE FOR WATER RESOURCES FACILITIES AT THE U.S. BUREAU OF RECLAMATION

Nathan Snorteland[47]
Elizabeth Dinneen[48]

ABSTRACT

The U.S. Bureau of Reclamation has been using risk to evaluate its structures since 1997. In the last 10 years, the way Reclamation uses risk information to manage dam safety across its inventory has developed gradually and steadily. Today, risk is used at the failure mode level to determine a course of action and at the facility level to determine the risk exposure. Risk is also used at the program level to assign resources, budget for studies and modifications, and justify potential structural modifications to Congress. Recently, Reclamation also began using risk to assess its own performance for the Office of Management and Budget. This paper will examine the various levels of detail and levels of effort used to accomplish Reclamation's objective of reliably delivering water and power. At each step, the available information, strategies, and decision-making processes will be explained.

[47] Program Manager, Dam Safety Office, U.S. Bureau of Reclamation, nsnorteland@do.usbr.gov, P.O. Box 25007,Denver, CO 80225
[48] Deputy Chief, Dam Safety Office, U.S. Bureau of Reclamation, edinneen@do.usbr.gov, P.O. Box 25007, Denver, CO 80225

NOTES

USACE DAM SAFETY PROGRAM — TRANSITION TO RISK MANAGEMENT

Eric Halpin, P.E.[49]
Andy Harkness, P.E.[50]

ABSTRACT

The U.S. Army Corps of Engineers (USACE) has been using a Portfolio Risk Assessment approach to influence dam safety budget decisions since 2005. Over the past three years the Corps has been developing new policies, procedures, and methodologies to support risk management practices. The Corps' end-state Dam Safety Program will be centrally managed and decentrally executed. Risk assessments will be used as the primary management tools providing fundamental information to improve the effectiveness and efficiency of decision making. The overall risk management framework includes screening portfolio risk analysis, prioritization risk assessment, and detailed site specific risk assessment. These may include prioritization of structural remediation, staged fixes, interim risk reduction measures, and investment in studies and investigations. Each level of analysis is complementary and collectively serves as a mechanism to construct cost effective risk reduction pathways for individual projects, strategies for portfolio management, and information for risk communication within USACE and externally to the public. This paper will examine USACE's transition to a risk informed dam safety program.

[49] Special Assistant for Dam Safety, U.S. Army Corps of Engineers, Headquarters, U.S. Army Corps of Engineers; 441 G Street NW, Washington DC, 20314 Eric.C.Halpin@usace.army.mil
[50] Technical Manager, Engineering Risk and Reliability Directorate, U.S. Army Corps of Engineers, Pittsburgh District; 1000 Liberty Avenue, Pittsburgh, PA 15222-4186 Andy.Harkness@usace.army.mil

NOTES

BEYOND BLACK AND WHITE
RISK-INFORMED DECISION MAKING IN A REGULATORY ENVIRONMENT

Patrick J. Regan, P.E.[51]
Douglas D. Boyer, C.E.G., P.E.[52]

ABSTRACT

The dam safety profession has moved beyond the point where all dams were viewed in a black and white world; either safe or unsafe. It is recognized that all dams have some probability of failure, albeit very small in most cases, and therefore, given the consequences of a dam failure, some risk. It is also recognized that many dam failures and incidents are not caused by any of the three traditional focuses of engineering analysis – static, flood, and seismic stability, but instead are the result of other factors including piping, overtopping by floods less than the design flood, failure of control systems and deficiencies or weaknesses in an owner's dam safety program. Risk assessment methodologies provide a means to assess all potential failure modes, an ability to assess the safety of dams across the whole range of grays between black and white, a better understanding of the probability and consequences of failure, the ability to capture the uncertainty inherent in any analysis, and focus for surveillance and monitoring systems, training programs, operation and maintenance programs, and safety inspections.

The Federal Energy Regulatory Commission (FERC) took an initial step towards utilizing risk assessment methodologies by incorporating Potential Failure Mode Analysis into our program in 2002. The FERC is currently working with Reclamation and the U.S. Army Corps of Engineers (USACE) to develop a joint federal guideline on risk assessment and is independently developing an internal guidance document to direct its efforts towards incorporating risk assessment methodologies into a risk-informed dam safety program.

[51] Regional Engineer, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, 805 SW Broadway, Suite 550, Portland, Oregon, 97205, Patrick.Regan@FERC.gov
[52] Supervisor, Dam Safety Engineering, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, 805 SW Broadway, Suite 550, Portland, Oregon, 97205, Douglas.Boyer@FERC.gov

NOTES

JOINT DEVELOPMENT OF A RISK MANAGEMENT AND ASSESSMENT STRATEGY FOR FEDERAL DAM AND LEVEE OWNERS

Andy Harkness[53]
Nathan Snorteland[54]
Eric Halpin[55]
Brian Becker[56]

ABSTRACT*

The U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation have begun joint development of risk management strategies, methods, and guidelines for dam and levee safety. Over the course of the next several years, the two agencies will be cooperating to standardize the methods and practices they and their contractors use to evaluate risks at their facilities. The two agencies own nearly 900 high and significant hazard dams and more than 2,000 levees. The cooperation between the Corps and Reclamation will include nearly every aspect of dam safety risk management from risk tolerability to calculating uncertainty. Already, several tools have been developed and many more are planned. This paper will detail the risk management plan, what it means for the two agencies, and what it means for A/E contractors.

[53] U.S. Army Corps of Engineers, Technical Manager, Engineering Risk and Reliability Directorate, U.S. Army Corps of Engineers, Pittsburgh District; 1000 Liberty Avenue, Pittsburgh, PA 15222-4186 Andy.Harkness@usace.army.mil
[54] Program Manager, Dam Safety Office, Bureau of Reclamation, PO Box 25007, 84-44000, Denver, CO 80225-0007, nsnorteland@do.usbr.gov
[55] Special Assistant for Dam Safety, U.S. Army Corps of Engineers, Headquarters, U.S. Army Corps of Engineers; 441 G Street NW, Washington DC, 20314 Eric.C.Halpin@usace.army.mil
[56] Chief, Dam Safety, Dam Safety Office, Bureau of Reclamation, PO Box 25007, 84-44000, Denver, CO 80225-0007, bbecker@do.usbr.gov
*This paper is not included in the Conference Proceedings CD.

NOTES

SOCIETAL RISK TOLERANCE AND SAFETY GUIDELINES — HOW SAFE DO DAMS NEED TO BE?

Nathan Snorteland[57]
Doug Boyer[58]
Dan Grundvig[59]

ABSTRACT*

Society and individuals in society have a natural aversion to risks in general; however, they judge risks from various sources quite differently. As individuals, we accept much higher risks from things like smoking or drinking, but do not tolerate high risks from dying in a plane crash. Despite having this natural aversion to risk, societies also have an unconscious acceptance that large natural events, whether they be floods or earthquakes, are somewhat inevitable. This tolerance of risks manifests itself in many ways; political action may be taken, protests may be made, changes are made to lifestyles or habits, and other more subtle actions may be taken. Many of these actions are difficult to evaluate. Following the Teton Dam failure in 1977, several of these actions were evident. A substantial national review of all dams was undertaken by the federal government and the National Dam Safety Acts of 1978 and 1983 were passed. Those were examples of political and legislative action taken when society – through their legislative representatives – felt uncomfortable with the risks posed by water resources structures. Guidelines used by Reclamation, other water resources entities, and other governments are essentially a reflection of the tolerance society has for the perceived frequency of dam failures. This paper will examine the place that dams have among the many risks posed by natural and man-made events.

[57] Program Manager, Dam Safety Office, Bureau of Reclamation, PO Box 25007, 84-44000, Denver, CO 80225-0007, nsnorteland@do.usbr.gov
[58] Dam Safety Chief, Pacific Northwest Division, Federal Energy Regulatory Commission, 101 S.W. Main Street, Portland, OR 97204, 503-552-2711
douglas.boyer@ferc.gov
[59] Manager, Safety, Security, and Dam Safety Division, Upper Colorado Region, Bureau of Reclamation 125 South State Street, Salt Lake City, UT 84138, 801-524-4161, dgrundvig@uc.usbr.gov
*This paper is not included in the Conference Proceedings CD.

NOTES

CONSIDERATION OF EXTREMELY REMOTE LOADING CONDITIONS FOR A DAM WITH HIGH DOWNSTREAM CONSEQUENCES

Phoebe Percell, PE[60]
Ernest Hall, PE[61]

ABSTRACT

The Bureau of Reclamation (Reclamation) makes dam safety decisions based on risk estimates. Static, hydrologic, and seismic potential failure modes are identified for a facility, and probabilities of failure and risks are estimated for each potential failure mode. Risk is defined as the probability of failure for a given failure mode multiplied by the potential loss of life for the potential failure mode. As consequences increase, acceptable probability of failure decreases for a given failure mode.

Recently, Reclamation conducted two analyses to estimate the risks for Folsom Dam. Folsom Dam is a concrete gravity structure with embankment wing dams and multiple dikes located on the American River just upstream of Sacramento, California Risk for Folsom Dam was estimated using extremely remote loading conditions due to the high downstream consequences associated with the structure.

The first analysis involved estimating large hydrologic events and routing these events through Folsom Dam. The flood routings were performed to evaluate the potential for dam/dike failure due to overtopping. The release operations, gate openings, and gate availability were varied to simulate different possible scenarios while passing a large flood. Risk estimates were made based on freeboard/overtopping estimates for the given scenarios.

The second analysis used extreme seismic events to estimate potential sliding of the dam at the foundation contact. Earthquakes with an occurrence interval as remote as approximately 200,000 years were used in this analysis. Risk estimates were generated based on the sliding estimates from these analyses.

[60] Phoebe Percell, Civil Engineer, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, ppercell@do.usbr.gov
[61] Ernest Hall, Civil Engineer, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, ehall@do.usbr.gov

NOTES

GENERALIZED EVENT TREE ALGORITHM AND SOFTWARE FOR DAM SAFETY RISK ASSESSMENT

Anurag Srivastava[62]
David S. Bowles[63]
Sanjay S. Chauhan[64]

Event Tree Analysis is a commonly used method in dam safety risk analysis modelling. Available software tools for performing event tree analyses lack the flexibility to efficiently address many important factors in dam safety risk analysis. As a result, spreadsheets have been used, sometimes including Visual Basic macros, to perform these analyses. This approach, however, lacks generality, and application to a specific dam or modification to the event tree structure can require substantial effort. In response to these limitations, we developed a generalized event tree analysis tool: DAMRAE (DAM safety Risk Analysis Engine). It includes a graphical interface for developing and populating an event tree as well as a tool for calculating and post-processing an event tree risk model for dam safety risk assessment in a highly flexible manner. This paper describes the underlying theoretical and computational logic employed in the current version of DAMRAE, and provides examples of the screens in the current version of DAMRAE for an application to a US Army Corps of Engineers (USACE) dam. The paper closes with conclusions about the capabilities of DAMRAE and a summary of plans for its further development.

[62]Graduate Research Assistant, Utah Water Research Laboratory, Utah State University, Logan, Utah. anurags@cc.usu.edu
[63]Professor and Director, Institute for Dam Safety Risk Management, Utah Water Research Laboratory, Utah State University, Logan, Utah, and Managing Principal, RAC Engineers & Economists, Providence, Utah. David.Bowles@usu.edu
[64]Research Assistant Professor, Institute of Dam Safety Risk Management, Utah Water Research Laboratory, Utah State University, Logan, Utah, and Senior Risk Engineer, RAC Engineers & Economists, Providence, Utah. Sanjay.Chauhan@usu.edu

NOTES

POTENTIAL FAILURE MODES (PFM) AND THE PFM RESOURCE TOOL

Justin Nettle, P.E.[65]
Jeffrey A. Esterle, PG, P.E.[66]

ABSTRACT

The PFM Resource tool is an attempt to collect the knowledge gained from the FERC's Dam Safety Performance Monitoring Program (DSPMP), specifically the Potential Failure Modes Analysis (PFMA). The PFMA identifies the most significant potential failure modes (PFMs) for the structure being reviewed as well as suggesting risk reduction and surveillance and monitoring options for the identified PFMs. By compiling the failure mode information from completed PFMA reports into a useable format, this information can be utilized as a resource tool and applied to other projects of interest. The PFM Resource Tool (PFMRT) is meant to be a learning tool which can be utilized by the dam safety community to help identify common failure modes for different types of dams as well as provide risk reduction and surveillance and monitoring options to identify failure mode indicators.

This paper discusses the development and uses of the PFMRT including a discussion of what constitutes a credible PFM; an overview of FERC's PFMA process; and the type of information that is available in the PFMRT and how it is organized. In addition, discussions on how the tool can be used to identify PFMs and assist in developing risk reduction measures and monitoring programs; and what is envisioned for the future of the resource tool including continual updates and additions of PFMs by the dam safety community.

[65] Civil Engineer, FERC, Division of Dam Safety and Inspections, Portland Regional Office, 503-552-2714, justin.nettle@ferc.gov
[66] Civil Engineer, USACE, Louisville District, Geotechnical and Dam Safety Section, Civil Engineering Branch, 502-315-6460, Jeffery.A.Esterle@usace.army.mil

NOTES

SCREENING UPDATE FOR PORTFOLIO RISK ANALYSIS FOR U.S. ARMY CORPS OF ENGINEER DAMS

Jeffrey T. McClenathan, P.E.[67]
Andy Harkness, P.E.[68]

ABSTRACT

As part of a move to risk informed decision making, the U.S. Army Corps of Engineers (USACE) developed and began to implement a Screening Portfolio Risk Assessment (SPRA) process for Dam Safety in 2005. The screening process considers loading frequency, an engineering rating to estimate a relative probability of failure, and both human life and economic consequences of failure. Since 2005, a total of 202 dams have been screened from the estimated 600 dams in the USACE portfolio. The relative human life and economic risks from the SPRA process were used to determine to determine initial ratings in the Dams Safety Action Classification (DSAC) system. This system was developed to categorize the type and urgency of actions based on the SPRA relative results. Projects with these DSAC classifications of I, II, and III have extremely high to moderately high risk and confirmed or unconfirmed dam safety issues. Dams with the DSAC rating of I are considered to have urgent and compelling reasons to act and a DSAC III rating dams are considered significantly inadequate. The dams evaluated included flood control, navigation, and multi-purpose dams. The remaining dams in the USACE Portfolio will be screened by the end of 2009 but is dependent on the availability of funding.

The results of the SPRA were used in determining funding requirements for dams. The limited funds associated with dam safety studies and dam modifications were prioritized using this risk based information from SPRA and their assigned DSAC ratings. In addition, development of EC 1110-2-6064, Interim Risk Reduction Measures, requires all dams classified in the Dam Safety Action Classifications (DSAC) I, II, and III to prepare a interim risk reduction plan and implement risk reduction measures. Projects with DSAC I, II, and III ratings are projects with the highest overall risk in the USACE portfolio using the SPRA methodology.

[67] Hydraulic Engineer, Engineering Risk and Reliability Directorate, SPRA Coordinator, U.S. Army Corps of Engineers, Omaha District; 1616 Capitol Avenue, Omaha, NE 68102-4908; jeffrey.t.mcclenathan@usace.army.mil
[68] Structural Engineer, Technical Lead, Engineering Risk and Reliability Directorate, U.S. Army Corps of Engineers, Pittsburgh District; 1000 Liberty Avenue, Pittsburgh, PA 15222-4186 andy.harkness@usace.army.mil

NOTES

USACE PERIODIC ASSESSMENTS — A RISK-INFORMED INSPECTION PROGRAM

Troy S. O'Neal, Ph.D., P.E.[69]

ABSTRACT

The U.S. Army Corps of Engineers (USACE) has developed a risk-informed periodic inspection process known as Periodic Assessments (PA). The PA has been Beta tested and will be linked to more advanced risk assessments as it becomes a routine and integral part of the overall risk reduction strategy for USACE's Dam Safety program. The objective of the PA is to reduce the overall project risk by actively seeking both standard and non-standard inter-related potential failure modes (PFM) with linking targeted field inspections and future performance monitoring to these identified PFMs. This paper provides a general overview of the PA process and the author's experience with development, implementation of this new USACE assessment program.

[69] Dam Safety Program Manager, U.S. Army Engineer Corps of Engineers, Louisville District, 600 Dr. Martin Luther King, Jr. Place, Louisville, KY, USA 40202, Troy.s.oneal@ usace.army.mil

NOTES

INTERIM RISK REDUCTION MEASURES FOR DAM SAFETY

Timothy M. O'Leary, P.E.[70]

ABSTRACT

Interim Risk Reduction Measures (IRRM) are an integral part of the risk-informed management of the Dam Safety Program of the U.S. Army Corps of Engineers (USACE). IRRM are an "in-the-meantime plan" for dam operations to reduce the probability and consequences of catastrophic failure to the maximum extent reasonably practical while inspections, investigations, testing, and studies take place which could ultimately determine whether or not the project is a candidate for significant repairs. This paper provides a general overview of IRRM from USACE's EC 1110-2-6064 and the author's experience with development, implementation, and review of IRRM Plans.

[70] Regional Technical Specialist, Geotechnical Engineer, U.S. Army Corps of Engineers, Louisville District, 600 Dr. Martin Luther King, Jr. Place, Louisville, KY, 40202, Timothy.M.OLeary@USACE.army.mil

NOTES

UNCERTAINTIES IN LOW-PROBABILITY ESTIMATES OF SEISMIC HAZARD: IMPLICATIONS OF A CONSTANT RISK GOAL FOR DAM SAFETY

Larry Anderson[71]
Jon Ake[72]

ABSTRACT

To assess the risks associated with a natural hazard (i.e., seismic events in this case) the risk is expressed as the product of the probability of failure times the consequences of that failure. This requires that the seismic hazard at the site, and the conditional probability of failure given that hazard, be specified within a probabilistic framework. One inevitable result of pursuing a constant risk goal is that as the consequences of failure become larger, the conditional probability of failure must become smaller to satisfy the goal. Thus, decision makers are often asked to consider very low probability events, which in turn have very large uncertainties associated with them.

The uncertainties in recurrence interval (or slip rate) for seismogenic faults are usually significant, even for well studied, high slip rate faults. However, for faults with low to very low activity rates, the assessment of activity is subject to very large uncertainties (one to two orders of magnitude). For situations where the hazard (i.e., ground motion) levels only need to be specified down to "moderate" annual probabilities of exceedence (APE), such as 10^{-4} /yr, these uncertainties do not appear to have a major impact on the results. However for lower probabilities these uncertainties become very important.

The Foothills fault system (FFS) is a 350-km-long, 50- to 100-km-wide northwest-striking zone of faults within the Sierra Nevada Foothills. Initial studies of the FFS considered the FFS to be a zone of partially reactivated normal faults. Recent studies suggest that the system may have a significant dextral or oblique component of slip. For the site we evaluated, different interpretations of the sense of slip, slip rate, and source geometry were incorporated through the use of logic trees. In addition to the uncertainty in seismic source characterization of the FFS, the uncertainties in characterization of the background or areal source zone and in ground motion attenuation models were also included.

The results of the probabilistic seismic hazard analysis confirm earlier results in the area that suggest for APEs > 10^{-4} , the hazard is dominated by moderate magnitude events occurring within the western Sierra Nevada areal source zone. However, for smaller APEs the FFS dominates the hazard. Due to the significant uncertainties in the characterization of the FFS, the uncertainty in probability for a specific ground motion level becomes very high for ground motion levels at the annual probabilities of interest for a high consequence facility.

---

[71] U.S. Bureau of Reclamation, Technical Service Center, Denver, CO 80225 (landerson@do.usbr.gov)
[72] U.S. Bureau of Reclamation, Technical Service Center, Denver, CO 80225 (current address: U.S. Nuclear Regulatory Commission, Washington, D.C) (jpa2@nrc.gov)

NOTES

EXTREME FLOOD PROBABILITY ESTIMATION METHODS FOR DAM SAFETY RISK ANALYSIS

John F. England, Jr., Ph.D., P.E., P.H., D.WRE[73]
Robert E. Swain, P.E., D.WRE[74]

ABSTRACT

The Bureau of Reclamation has developed and applied several methods in order to estimate extreme floods and probabilities for dam safety risk analysis. Results are portrayed as hydrologic hazard curves. Hydrologic hazard information consists of a flood frequency analysis and frequency flood hydrographs for a full range of Annual Exceedance Probabilities (AEPs). AEP estimates are made for peak flows, runoff volumes and reservoir elevations to cover the range of values needed for dam safety decision making. The approach to estimate a hydrologic hazard curve typically evolves from simpler to more detailed approaches. The hydrologic hazard methods that have been used by Reclamation to date include flood frequency with paleoflood data, hydrograph scaling and volumes, the GRADEX method, the Australian Rainfall-Runoff method, stochastic event-based precipitation runoff modeling with the stochastic event flood model, and stochastic rainfall-runoff modeling with storm transposition and the TREX model. The procedure for developing a hydrologic hazard curve considers the dam safety decision criteria, potential failure modes, dam characteristics, available data, possible analysis techniques, resources available, and tolerable level of uncertainty. Recent comparisons in California and Colorado have shown relatively close agreement between stochastic rainfall-runoff models and paleoflood-based frequency curves in some detailed study cases. This paper summarizes the approaches used and some case study results.

---

[73]Hydraulic Engineer, Flood Hydrology and Meteorology, 86-68530, Bureau of Reclamation, Denver, CO 80225, jengland@do.usbr.gov
[74] Consulting Hydrologist/Engineer, Littleton, CO 80127, robertswain@hotmail.com

NOTES

EVALUATION OF SEEPAGE AND POST-SEISMIC STABILITY CONCERNS ISABELLA AUXILIARY DAM, CALIFORNIA

Mike Knarr, P.E., S.E.[75]
Elena Sossenkina[76]
Scott Anderson, P.E.[77]
Ronn Rose[78]
Keith Ferguson, P.E.[79]
Rick Britzman, P.E.[80]

ABSTRACT

Isabella Dam, constructed between 1948 and 1953, is a high-hazard dam located on the Kern River upstream of Bakersfield, California. The dam and reservoir owned and operated by the U.S. Army Corps of Engineers (the Corps) provide major flood control, water supply and recreation benefits to the region. Two embankment dams, the Main Dam and the Auxiliary Dam, with maximum heights of approximately 185 and 100 feet, respectively, create the reservoir. Other principal facilities of the project include main and auxiliary (Borel Canal) outlet works, and an emergency spillway. The outlet works at the Auxiliary Dam releases water to the Borel Canal, which provides water for the Southern California Edison (SCE) Company's Borel Powerhouse downstream of the dam. The maximum storage capacity of the reservoir is 570,000 acre-feet at the emergency spillway crest and 842,000 acre-feet at the maximum spillway design flood pool elevation.

Recent studies by the Corps have identified a number of major safety concerns, including seepage and post-seismic stability of the Auxiliary Dam and its foundation. This paper provides an overview of the Isabella Dam safety project to date. It includes a description of the design and construction of the Auxiliary Dam and Borel Canal outlet works and summarizes the seepage investigation program and the post-earthquake stability evaluations.

[75] Principal Structural Engineer, Kleinfelder, Inc., Redlands, CA, mknarr@kleinfelder.com
[76] Principal Geotechnical Engineer, Kleinfelder, Inc., Golden, CO, esossenkina@kleinfelder.com
[77] Principal Geotechnical Engineer, Kleinfelder, Inc., Albuquerque, NM, sanderson@kleinfelder.com
[78] Senior Engineering Geologist, Sacramento District Corps of Engineers, Sacramento,CA, Ronn.S.Rose@spk01.usace.army.mil
[79] National Surface Water Resources Program Director, Kleinfelder, Inc., Golden, CO, kferguson@kleinfelder.com
[80] Dam Safety Program Manager, Sacramento District Corps of Engineers, Sacramento, CA, Richard.A.Britzman@USACE.Army.Mil

NOTES

SINKHOLE INCIDENT AT SWINGING BRIDGE DAM

David E. Capka, P.E.[81]
Eugene Gall, P.E.[82]

ABSTRACT

Completed in 1929, Swinging Bridge Dam is a 135-foot high, 965-foot-long hydraulic fill dam located on the Mongaup River upstream of its confluence with the Delaware River near Forestburgh, New York. Differential settlement and cracking of the penstock and diversion tunnel duplex conduit occurred during or shortly after construction. This cracking led to seepage outbreaks on the downstream slope of the dam and some piping of silt from the embankment into the tunnel during reservoir filling. The cracks in the tunnel and penstock were repaired in the early 1930s.

In May of 2005, a large sinkhole appeared on the crest of the dam. Emergency actions were taken to address the immediate threat to the dam. Following a reservoir drawdown, investigations were performed and remedial measures designed to allow the dam to continue operation. The remedial measures included low- and high-mobility grouting adjacent to the conduit, installation of a filter diaphragm along the downstream end of the conduit, additional drains and filter blankets, and infilling of the conduit structure. This paper will discuss the construction history of the dam, the performance history of the dam, the 2005 sinkhole incident and response, and the subsequent remedial measures undertaken to ensure the dam continues to operate safely.

[81] Senior Geotechnical Engineer, Division of Dam Safety and Inspections, Federal Energy Regulatory Commission, Office of Energy Projects, 888 First St. N.E., Washington, DC 20426.
[82] Supervisor, Dam Safety Engineering, New York Regional Office, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, 19 West 34th Street, Suite 400, New York, NY 10001.

NOTES

BIG EASY LEVEE DESIGN: PROPOSED IMPROVEMENTS TO THE EXISTING 17TH STREET AND LONDON AVENUE CANAL LEVEES

Del Shannon, P.E.[83] John Koontz, P.E.[84]
Lawrence Almaleh, P.E.[85] Molly O'Connor[86]

ABSTRACT

On the morning of Monday, August 29, 2005, Hurricane Katrina hit the city of New Orleans, Louisiana causing numerous levee failures. In the Jefferson and Orleans Parishes one levee failure occurred on the east side of the 17th Street Canal and two levee failures occurred on the London Avenue Canal – one each on the west and east sides. All of the failures occurred in section of the levee where I-Walls were installed for parallel flood protection. Because of their location, these failures were particularly devastating to Orleans Parish. Several feet of water covered nearly all of Orleans Parish for weeks after the hurricane.

The 17th Street, Orleans and London Avenue Outfall Canals carry stormwater from pumping stations located in Orleans and Jefferson Parish north, discharging this water into Lake Pontchartrain. As with most failures, a combination of circumstances caused these events and these failures have been studied in great detail in the last two and a half years. However, these levees, which have a combined length of over 13 miles, must still protect those living in Orleans and Jefferson Parish.

Starting with the knowledge of the existing levee and flood wall designs and an improved understanding of the underlying geotechnical conditions at these three canal locations, this paper outlines the current design alternatives being considered for improving the factor of safety for water elevations of 6, 8 and 10 feet (NAVD) for these structures. The alternatives currently being considered include: 1) new I-Wall construction; 2) new T-Wall construction: and 3) additional, but unproven, methods such as constructing a berm on the protected side of the levees, cutoff walls, and drains

There are advantages and disadvantages to each of these alternatives, including significant cost differentials, performance during flood and hurricane events, land purchase, condemnation and demolition of existing structures, constructability concerns, urban construction environment, and so on. This paper discusses the existing conditions of the levees, the investigations and analyses performed, the advantages and disadvantages of the design alternatives, and the recommend design for improving these structures.

---

[83]Dams, Levees and Reservoirs Group, Black & Veatch Corporation, 6300 S. Syracuse Way, Suite 300, Centennial, Colorado, 80111; 720-834-4243; ShannonDA@bv.com
[84]Geotechnical Engineer, Black & Veatch Special Projects Corporation, 6601 College Blvd., Overland Park, Kansas, 66211; 913-458-9028; KoonztJJ@bv.com
[74]Project Manager, Black & Veatch Special Projects Corporation, 6601 College Blvd., Overland Park, Kansas, 66211; 913-458-8034; AlmalehL@bv.com
[86]Geotechnical Engineer, Black & Veatch Special Projects Corporation, 6601 College Blvd., Overland Park, Kansas, 66211; 913-458-6083; OConnorMS@bv.com

NOTES

LONG TERM PRESSURE RELIEF SYSTEM PERFORMANCE FOR DAMS ON PERMEABLE FOUNDATIONS

Robert L. Arnold, P.E.[87]

ABSTRACT

The Pressure Relief System of Hardin Dam No. 3 has been maintained approximately annually by pumping tests which included data collection and analysis of system components for determining long term performance and remediation. Similar effort exists for Dams 2, 4, and 6; all being typical of pile founded, low head navigation dams. Of similar history are the systems of the locks associated with these dams, including Lock No. 1. Unlike for the dams, the lock systems can be characterized more as lock maintenance unwatering systems in which the pervious drains and relief wells can be independently measured for under seepage discharge. This independent lock system record allows a comparative assessment against the dams system's performance; and overall capability of wells relative to drains for general use. Pressure relief system details, history, maintenance and inspection, problems experienced, and individual system component performance are discussed and represented by pump test data verses time graphical charts collected from representative projects. Details are presented on the July 2004 discovery of foundation distress under the spillway stilling basin, including initial inspections by underwater camera which confirmed dislocated piping and drainage filter disturbance, thus inferring that voids are present under the stilling basin. The probable cause of the distress is described citing project history, including discussion on other possible causes. The current foundation distress is used to support long term performance and reliability conclusions and recommendations for selecting pervious drains relative to relief wells for most general application, with limited use of wells and only then in specialized applications where they are well suited. The Dam 3 distress is presented to assist engineers in forming best practices designs that minimize risks against an increasingly more serious, and as infrastructure ages, more frequently occurring problem associated with water resource structures and conveyance systems founded on or through permeable soils, and highly susceptible to erosion, seepage piping or settlement.

[87] Robert L. Arnold, P.E., Geotechnical Engineering Specialist, Little Rock District Corps of Engineers, 700 W. Capitol Ave., Little Rock, AR 72210-0867; robert.l.arnold@swl02.usace.army.mil

NOTES

CONTROL OF HYDROFRACTURING AT LAKE FORT SMITH DAM

Christopher Groves[88]
Mike Lambert[89]

ABSTRACT

The existing Lake Fort Smith Dam was raised 100 feet to increase municipal water storage capacity. The new dam is about 200 feet high from the bedrock foundation to the crest and about 2800 feet long. The project is notable in that few 200-foot-high dams have been recently constructed in the United States.

The site is in Northwest Arkansas where the topography consists of steep ridges and narrow valleys. Bedrock consists of sandstone and shale with a thin soil cover. A rock fill dam was an obvious choice, but little clay was available in the valley or on the slopes. The sandstone was not well cemented, so good aggregate was scarce for manufacturing filter material. The design resulted in rock fill shells upstream and downstream, with relatively thin, two-stage filters and a clay core. With this geometry, there was a concern about hydrofracturing of the clay core resulting in uncontrolled seepage. Finite difference analysis showed that the there would be zones with low minor principal stress. To mitigate the risk, the filters were thickened in the zones where hydrofracturing was most likely and foundation preparation was conducted in a manner that would also reduce the potential for hydrofracturing.

The search for suitable materials and the processing of materials, as well as foundation preparation, are documented in the report.

[88] Senior Vice President Shannon & Wilson, cbg@shanwil.com, 314-699-9660
[89] Associate Shannon & Wilson, mtl@shanwil.com, 314-699-9660

NOTES

WHERE CLAY MEETS SAND: COMPARING A SIMPLE FILTER SIMULATION WITH FILTER TESTS

Christopher Hill[90]

ABSTRACT

Hill and Beikae (2006) developed a simple simulation of filter performance utilizing the entire grain size distributions of the base (core) soil and the filter soil. The simulation was developed to improve understanding of the phenomenon of the base-filter interaction, and also to provide guidance in situations where existing filters do not meet filter criteria. In the 2006 paper, the results of the interaction between several uniform filters and a near-uniform base soil were compared. The simulation was shown to agree fairly well with behavior that would be expected based on relationships expressed by Foster and Fell (2001).

The simulation randomly selects a single particle from the base soil, assumes it is transported via a crack or slot to the face of the filter soil, and then randomly selects three particles from the filter and calculates the size of the opening formed by the three particles. If the particle passes through the opening, the new position within the filter layer is calculated, and the process is repeated. If the particle becomes lodged in the filter zone, the gradation of the filter is adjusted. If the particle became lodged on the first collision, then it becomes added to a "filter cake" layer forming on the upstream face of the filter. The program presented uses computer graphics to help convey the "lodging" of transported particles from the core into the filter material, and how that affects the development and performance of the filter cake layer, the gradation of the filter and the filter performance.

Foster and Fell (1999) reported results of 62 laboratory tests using the no-erosion filter and continuous erosion filter tests, and the results of the filter simulation are compared with the results of these tests. The case of Balderhead Dam, which exhibited poor filter performance, was also analyzed using the filter simulation. The simulation results are summarized by a single value, a shape factor S, which when greater than one indicates rapid sealing of the filter, conservatively predicted either no erosion or "some erosion" in the cases identified.

[90] Senior Engineer, Metropolitan Water District of Southern California, 700 N. Alameda St., Los Angeles, CA, phone: 213-217-7969 email: chill@mwdh2o.com

NOTES

SEEPAGE ANALYSIS AND INITIAL PERFORMANCE OF THE BIG SAND WASH RESERVOIR ENLARGEMENT

Jaco Esterhuizen[91]
Mike Mickelson[92]
Nason J. McCullough[93]
Lee Wimmer[94]

ABSTRACT

The Big Sand Wash Dam in northeastern Utah was raised to enlarge the reservoir capacity from 12,100 to 24,200 acre-feet. Extensive rehabilitation, in addition to raising the main and saddle dams, was conducted for several reasons, including: 1) the dam cores (and shells) were originally constructed from silt and silty sand materials with a high erosion potential, 2) the saddle dams lacked modern filter/drain systems and the main dam's filter only extended part way to the top of the dam, and 3) significant seepage was occurring through the abutments.

The enlargement project included:

- reconstruction of the dam and increasing the height by 26 feet,
- constructing a new clay core as the primary embankment seepage barrier,
- installation of a three-line grout curtain as the primary foundation seepage barrier,
- installation of a shallow concrete cutoff wall as a positive seepage barrier at the embankment-foundation interface, and
- construction of a new internal filter and drainage system, including chimney, blanket, and toe drains.

This paper provides practice-oriented insights based on the predicted and measured seepage behavior of the main dam during first filling of the reservoir. Piezometric levels and seepage flows predicted using numerical seepage analyses are compared with measured water levels in standpipe piezometers and measured drainage quantities, respectively.

The paper also discusses construction aspects of the shallow cutoff wall, such as the suitability of the bedrock for trenching, trenching on steep side-slopes, cleaning of the trench, and constructability details to extend the cutoff wall into the core of the dam.

[91] Project Engineer, CH2M HILL, Corvallis, OR 97330, Jaco.Esterhuizen@ch2m.com
[92] Project Manager, CH2M HILL, Salt Lake City, UT 84111, Mike.Mickelson@ch2m.com
[93] Project Engineer, CH2M HILL, Corvallis, OR 97330, Nason.McCullough@ch2m.com
[94] CUPCA Construction Manager, Central Utah Water Conservancy District, Orem, UT 84058, lee@cuwcd.com

NOTES

INFLUENCE OF VERTICAL SHAKING ON EMBANKMENT DAM SEISMIC RESPONSE

Gilles Bureau, P.E., G.E.[95]
William A. Rettberg, P.E.[96]
Jacob Eymann, P.E.[97]

ABSTRACT

The vertical component of ground motion has typically been ignored in most dynamic analyses of embankment dams. Yet, and especially in the near-field, vertical motion can increase the severity and significantly contribute to the overall characteristics of earthquake-induced ground shaking. The lines of reasoning used in the past to justify not considering that component of motion in simplified or equivalent-linear finite element analyses of embankment dams no longer apply to modern nonlinear analysis techniques.

The authors recently re-evaluated an existing embankment dam with *FLAC* and used several sets of spectrum-compatible input acceleration histories, with or without the vertical component of base motion. For the specified MCE and study dam, peak crest settlements computed in the analyses with vertical input motion ranged from being about the same to nearly twice greater than without it, and maximum slope deformations ranged from near equal to about 50 percent larger. This example, therefore, demonstrates the significance of adequately simulating potential earthquake motion, both horizontal and vertical.

[95] Senior Consultant, GEI Consultants, Inc., 2201 Broadway, Suite 321, Oakland, CA 94612, gbureau@geiconsultants.com
[96] Vice President, GEI Consultants, Inc., 2201 Broadway, Suite 321, Oakland, CA 94612, wrettberg@geiconsultants.com
[97] Project Manager, El Dorado Irrigation District, 2890 Mosquito Road, Placerville, CA 95667, jeymann@eid.org

NOTES

METHODS TO EVALUATE SEISMIC RISKS FOR EMBANKMENT DAMS

Karl Dise[98]
Nathan Snorteland[99]

ABSTRACT

The Bureau of Reclamation uses risk analysis to help manage its dam safety program. This paper describes Reclamation's risk analysis methodology for seismic loading of embankment dams. Earthquake-induced accelerations, SPT blow count, pre-earthquake freeboard, and life loss are modeled as random variables. Liquefaction likelihood is modeled as a function of blow count, confining pressure, fines content, cyclic shear stress ratio, and earthquake magnitude. Additional functional relationships modeled include: residual shear strength as a function of blow count, crest deformation as a function of residual shear strength, post-earthquake freeboard as a function of crest deformation and pre-earthquake freeboard, and breach progression likelihood as a function of post-earthquake freeboard and embankment erodibility characteristics. Uncertainties about the functional relationships are also modeled using random variables. Monte Carlo simulation generates scatter-plots depicting annual probability of life loss from thousands of possible random variable combinations. Information gleaned from the model construction and the probability estimation process is used to outline the state of knowledge for an embankment facility, to explicitly characterize parameter uncertainties, and to identify key contributors to risk. This process provides a means to build a case to support decisions regarding workload prioritization for Reclamation's entire inventory and for future actions proposed for specific dams.

[98] Geotechnical Engineer, Geotechnical Engineering Group 1, Technical Services Center, U.S. Bureau of Reclamation, kdise@do.usbr.gov, P.O. Box 25007, Denver, CO 80225
[99] Program Manager, Dam Safety Office, U.S. Bureau of Reclamation, nsnorteland@do.usbr.gov, P.O. Box 25007, Denver, CO 80225

NOTES

SIMPLIFIED ESTIMATION OF SEISMIC DEFORMATION FOR RISK ANALYSIS

Thomas G. Pace[100], PE
Jeffrey A. Schaefer[101], PhD, PE, PG
Timothy M. O'Leary[102], PE
Alan F. Rauch[103], PhD, PE

ABSTRACT

Evaluating the potential deformation of dams and levees subject to foundation liquefaction is a task that requires great effort. Complex numerical models are often used. The expense involved in such efforts necessarily makes them impractical in cases where a large number of sites must be investigated. Such is the situation faced by the U.S. Army Corps of Engineers, which is responsible for over 600 dam and levee sites nationwide. To correctly prioritize investigation and remediation efforts for such a large portfolio of facilities, the Corps of Engineers has implemented a review system that evaluates the risk of failure at each site for a number of failure modes. The Corps of Engineers identified the failure mode of overtopping due to liquefaction-induced crest movement as a weakness in the risk assessment process because of the lack of simplified tools for estimating deformation. This paper reviews a set of equations developed as a simplified tool to resolve this weakness. The equations were developed from regression analysis on a database of thousands of numerical model results.

[100] Senior Project Engineer, Stantec Consuting Services, Inc., 1409 North Forbes Road, Lexington, KY 40511, Tom.Pace@stantec.com
[101] Geotechnical Lead, Risk and Reliability DX, U.S. Army Corps of Engineers Louisville District, 600 Dr. Martin Luther King Jr. Place, Louisville, KY 40202, Jeffrey.A.Schaefer@lrl02.usace.army.mil
[102] Regional Technical Specialist, Geotechnical Engineer, U.S. Army Corps of Engineers Louisville District, 600 Dr. Martin Luther King Jr. Place, Louisville, KY 40202, Timothy.M.OLeary@USACE.army.mil
[103] Senior Geotechnical Engineer, Stantec Consuting Services, Inc., 1409 North Forbes Road, Lexington, KY 40511, Alan.Rauch@stantec.com

NOTES

SEISMIC REMEDIATION OF EMBANKMENT DAMS — ACCEPTING UPSTREAM SLOPE FAILURE

Steve Collins, P.E., PhD[104]
Kellie Marshall, EIT[105]

ABSTRACT

Dam designers and agencies responsible for dam safety historically have not accepted any mention of the word "failure" in their definition of allowable dam performance. In the early 1960's this philosophy was relaxed by necessity. The design of new dams and the evaluation of stability for existing dams started using peak ground accelerations that were much higher than the conventional 0.1g. This was based on new ground motion data that much larger accelerations do frequently occur during earthquakes. When these higher accelerations were used in pseudo-static analyses, slope stability Factor of Safety (FS) values much lower than 1.0 were produced, and in some sense "failure" was implied for well designed dams. In response, Newmark in 1965 presented his famous Rankine Lecture that pointed out a FS of less than 1.0 only implies that permanent deformations start to accumulate, which are often of minor magnitude, and do not in any way imply the dam has failed. Newmark's enlightenment was the start of viewing acceptable performance in terms of allowable displacements.

The alarming near release of the reservoir at the Lower San Fernando Dam in 1971 brought intense focus on liquefaction induced dam safety problems. Evaluation of existing dams, and design of new dams, directed resources toward eliminating potential liquefaction in the dam and foundation (excavate and replace, insitu densification) or construction of well compacted earthfill berms, cellular containment, or pile groups such that the impact of liquefaction in confined zones would limit overall deformations to a small value, on the order of 2 feet or less. In the 1980's and 90's, the level of sophistication of constitutive models and their incorporation into finite element/finite difference models saw dam remediations that were accepting much larger deformations, up to 40 feet for one large dam. Much of the geotechnical dam safety community is still reluctant to accept that these constitutive/FEM/FD models produce reliable large deformation results for critical dams.

The Federal Energy Regulatory Commission has been faced with requiring seismic analysis/remediation at a number of large earthen dams, typically hydraulic or semi-hydraulic fill, or well compacted dams founded on liquefiable foundations. This paper presents the analysis/remediation of four dams that have the potential for large scale upstream post seismic flow or mass movement, and this mass movement is considered acceptable. The key to reaching such a decision is confidence that all aspects of potential behavior, analysis, and input variables have been treated in a realistic but conservative manner. This includes specifying earthquake motion, stratigraphy, N values, liquefaction analysis procedures, undrained strengths of both liquefied and non-liquefied soils, drained versus undrained behavior, and stability analysis procedures.

[104] Principal Geotechnical Engineer, Division of Dam Safety and Inspections, FERC, Atlanta, GA
[105] Civil Engineer, Division of Dam Safety and Inspections, FERC, Portland OR Regional Office

NOTES

CONCRETE WALLS AND GROUT CURTAINS IN THE TWENTY-FIRST CENTURY: THE CONCEPT OF COMPOSITE CUT-OFFS FOR SEEPAGE CONTROL

Dr. Donald A. Bruce[106]
Trent L. Dreese[107]
Douglas M. Heenan[108]

ABSTRACT

The state-of-practice in the design, construction and verification of concrete cut-offs, and grout curtains, as dam seepage remediations is reviewed. Recent experiences when attempting to build concrete cut-offs through hard and highly permeable rock masses have led the authors to develop the concept of "composite cut-offs" for seepage control. A campaign of high quality drilling, permeability testing and grouting is first conducted to pretreat the very permeable and/or clay-filled zones, to seal the clean fissures, and to provide an extremely detailed geological basis upon which to design the location and extent of the subsequent concrete wall (if in fact needed). Bearing in mind that the average cost of a concrete wall is many times that of a grouted cut-off, and that there is currently a shortfall in industry capacity to construct the former, the concept of a "composite wall" is logical, timely and cost effective.

[106] President, Geosystems, L.P., P.O. Box 237, Venetia, PA 15367, U.S.A.; Phone: (724) 942-0570; Fax: (724) 942-1911; Email: dabruce@geosystemsbruce.com.
[107] Vice President, Gannett Fleming Inc., 207 Senate Avenue, Camp Hill, PA 17011, U.S.A.; Phone: (717) 763-7211 x2686; Fax: (717) 303-0346; Email: tdreese@gfnet.com.
[108] Vice President, Advanced Construction Techniques Ltd., 3935 Lloydtown Aurora Road, Kettleby, ON L0G 1J0, Canada; Phone: (905) 939-7755; Fax: (905) 939-9305; Email: dheenan@agtgroup.com.

NOTES

RISK-BASED DECISIONS AND DESIGN FOR SEISMIC DAM SAFETY MODIFICATIONS

Dennis L. Hanneman, P.E.[109]
David R. Gillette, P.E.[110]

ABSTRACT

Deer Creek dam, located in a highly seismic area of the Wasatch Mountains in Utah, was constructed in the 1930's. Only rudimentary approaches to earthquake engineering were employed in the original design due to the state of knowledge in existence at that time. Relatively recent engineering analyses concluded that the downstream portion of the dam is founded on liquefiable layers that may lose strength under strong earthquake loading. As a result of this strength reduction, large embankment deformations could occur, which could result in failure of the dam. A risk estimating team determined that the risk to the downstream population was above Bureau of Reclamation (Reclamation) guideline levels. Key inputs to the dam risk analysis model were results of 2-dimensional and 3-dimensional deformation analyses generated by the finite difference computer programs FLAC and FLAC^{3D}. Sensitivity studies were performed to aid in evaluating potential deformations resulting from various earthquake loadings, liquefied soil layers, and undrained residual shear strengths. Results of the deformation analyses were used to develop cumulative distribution functions for crest settlement under various earthquake loadings. These distributions and the reservoir operating history were utilized in a Monte Carlo simulation to obtain the freeboard remaining for 10,000 "realizations" of the model. The probability of dam failure was estimated for each realization of the risk model based on the amount of remaining freeboard and the amount of settlement experienced by the dam in each realization. Results of the risk analysis indicated that further risk reduction was warranted, and modifications including a crest raise are planned for 2008.

This paper is a synopsis of two Reclamation reports that evaluated the seismic risks at Deer Creek Dam.

[109] Civil Engineer, Bureau of Reclamation, Technical Service Center, Denver, CO 80225
dhanneman@do.usbr.gov
[110] Technical Specialist, Bureau of Reclamation, Technical Service Center, Denver, CO 80225
dgillette@do.usbr.gov

NOTES

THE INFLUENCE OF THE CULVERT ON THE LEAKAGE AT LOWER CARNO DAM

Jane Walbancke[111]
Andrew Rowland[112]
Lucy Mistry[113]

ABSTRACT

Lower Carno dam in South Wales is an earth embankment with a central puddle clay core and deep cut-off trench. The dam has a history of leakage and a succession of remedial works has been carried out. In January 2005 increased leakage flows from near the toe of the dam were reported. Investigations to trace the source of the flows were unsuccessful and as the rate of leakage increased rapidly, it was decided to empty the reservoir. During the course of emptying, settlement of the wave wall beside the culvert increased by 150mm.

This paper describes the history of the reservoir and the leakage. Most of the leakage was thought to be related to the culvert and draw-off shaft, particularly where the culvert passes through the core. Two main causes were thought to be operating, firstly the deterioration of the concrete and secondly hydraulic fracture and cracking of the clay core where it abutted the culvert. The ground investigation found no voids in the core but confirmed that the quality of the concrete was poor. The drilling also showed that the concrete surround to the culvert where it passed through the core trench was not as shown on the 'record' drawings and likely to be a major cause of cracking in the core.

The options of either repairing or decommissioning the dam were proposed. As the owners require the reservoir to meet their supply obligations, their preference is to carry out remedial works rather than decommission. Remedial works are directed at preventing further internal erosion and minimizing leakage.

[111] Technical Director, Black & Veatch, Grosvenor House, 69 London Road, Redhill, Surrey, RH1 1LQ, UK walbanckej@bv.com
[112] Technical Director, Black & Veatch, Grosvenor House, 69 London Road, Redhill, Surrey, RH1 1LQ, UK rowlanda@bv.com
[113] Senior Engineer, Black & Veatch, Grosvenor House, 69 London Road, Redhill, Surrey, RH1 1LQ, UK mistryl@bv.com

NOTES

FAILURE OF SWIFT NO. 2 FOREBAY DAM

Patrick J. Regan, P.E.[114]
Gary Huhta[115]
William N. Lagnion, P.E.[116]

ABSTRACT

Swift No. 2 Forebay Dam is an 80-foot-high earth embankment dam owned by Public Utility District No. 1 of Cowlitz County. The dam is located southwest of Mount St. Helens in southwest Washington. The dam is founded on a complex stratigraphy comprising recent alluvial material deposited by streams flowing off the slopes of Mount St. Helens, basalt flows, and older alluvial materials deposited by the Lewis River.

In April 2002, the Swift No. 2 Forebay Dam failed catastrophically. The failure was caused by a large sinkhole that formed in the soil-lined canal leading to a lava tube that connected with loose alluvium beneath the basalt flow. The water pressurized the foundation area, ultimately finding an exit at the toe of the embankment leading to rapid erosion of the embankment.

This paper presents the results of the forensic investigation and review of construction and operations documents and provides insights for dams constructed on similar foundation materials.

[114] Regional Engineer, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, 805 SW Broadway, Suite 550, Portland, OR, 97205, Patrick.Regan@FERC.gov
[115] Director of Power Management, Public Utility District No. 1 of Cowlitz County, 961 12th Ave., P.O. Box 3007, Longview, WA, 98632, GHuhta@CowlitzPUD.org
[116] Civil Engineer, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, 805 SW Broadway, Suite 550, Portland, OR, 97205, William.Lagnion@FERC.gov

NOTES

SWIFT NO. 2 HYDROELECTRIC PROJECT RECONSTRUCTION — FEATURES AND PROCEDURES ADOPTED TO MITIGATE DAM SAFETY RISKS

Thomas J. O'Brien, P.E.[117]
Steve Benson, P.E.[118]
Mike Pavone, P:E.[119]

ABSTRACT

The Swift No. 2 Hydroelectric Project (Project) is one of a series of hydroelectric developments located on the north fork of the Lewis River in Cowlitz, Clark, and Skamania Counties, Washington, approximately 60 miles north of Portland, Oregon. The Project before reconstruction included a soil-lined power canal, a wasteway, an upstream check structure, a powerhouse, and a switchyard. On April 21, 2002, without forewarning, a section of the power canal embankment at the forebay, where it was at its maximum height, failed within a period of a few hours, emptying the canal and destroying the powerhouse and switchyard. Embankment failure was attributed to a large sinkhole that formed in the forebay floor due to a lava tube within an underlying basalt flow, Cave Basalt, that connected with alluvium below the basalt. The water pressurized the foundation area, finding a release at the downstream toe of the embankment, which rapidly eroded the embankment and caused its collapse and breach.

Following investigation of the failure by others, Washington Group International (now the Washington Division of URS Corporation) was retained to perform the design investigations, analyses, designs, and construction engineering management of the reconstructed Project. The reconstruction engineering activities were performed with overview by a Board of Consultants approved by the Federal Energy Regulatory Commission (FERC). Measures to mitigate the risk of piping into the underlying basalt included treatment of the portion of the canal foundation underlain by basalt, reconstructing the canal with a concrete liner, providing a leak detection system beneath the liner, and installing a transition structure at the upstream edge of the basalt.

[117] Consulting Geotechnical Engineer, Washington Division of URS Corporation, 10900 N.E. 8th Street, Suite 500, Bellevue, WA 98004, tom.obrien@wgint.com
[118] Manager Geotechnical/Consulting Department, Washington Division of URS Corporation, 10900 N.E. 8th Street, Suite 500, Bellevue, WA 98004, steve.benson@wgint.com
[119] Manager of Engineering, Washington Division of URS Corporation, 10900 N.E. 8th Street, Suite 500, Bellevue, WA 98004, mike.pavone@wgint.com

NOTES

GEOTECHNICAL FOUNDATION CONSIDERATIONS FOR THE RECONSTRUCTION OF THE SWIFT NO. 2 POWER CANAL, WA

Sarah Wilkinson Kemp[120]
Stephen A. Benson[121]

ABSTRACT

In April 2002, an 80-foot-high section of the forebay embankment at the Swift No. 2 Hydroelectric Project failed, resulting in an uncontrolled release of water and material. The forebay and its embankments were underlain by up to 30 feet of native overburden soil, a 15- to 60-foot-thick basalt flow, and various alluvial and colluvial sediments. Embankment failure occurred when a seepage path developed between the forebay waters and the alluvium via a sinkhole and lava tube that connected with the bottom of the basalt. The water pressurized the foundation area where the basalt flow was thin finding release at the toe of the embankment, which quickly eroded the embankment causing its collapse. The water flow through the foundation caused erosion of alluvium below the basalt leaving a cavity zone below the basalt. Twenty-five-foot-high basalt cliffs formed an amphitheater-shaped hole in the breached embankment foundation. The drained canal revealed numerous other sinkholes, most of which were formed by silty native soils that had piped into other basalt openings or by cavities left by rotting vegetation. Geotechnical investigations concluded that the forebay foundation required structural improvement to support any reconstruction and that without proper reconstruction design, the canal was at risk from piping failures wherever the canal was underlain by basalt.

Geotechnical foundation considerations for the reconstruction design focused on 1) providing foundation support for the reconstructed canal/forebay and 2) limiting the opportunity for canal water intrusion and piping of foundation and embankment soils. A unique application of low mobility grouting was used to provide structural support in the 3-acre forebay. Other key foundation design elements included rock shaping, surface treatment of large openings, foundation load testing, removal of pipeable material, and the use of select leveling courses, engineered fill, and drainage blankets. These foundation improvements along with replacement of approximately 5,800 feet of original soil-lined canal with concrete-lined canal to prevent excessive canal leakage have lead to the reconstruction of a safe, reliable project that resumed operation in January 2006.

[120] URS, Washington Division, 10900 NE 8th Street, Suite 500, Bellevue, WA 98004. sarah.kemp@wgint.com
[121] URS, Washington Division, 10900 NE 8th Street, Suite 500, Bellevue, WA 98004. steve.benson@wgint.com

NOTES

EMERGENCY REMEDIAL ACTIONS AT A.V. WATKINS DAM

Bruce C. Barrett, P.E.[122]
Mark Bliss, P.E.[123]

ABSTRACT

A.V. Watkins Dam is a U-shaped, zoned earthfill dam approximately 14.5 miles long with a structural height of 36 feet. The dam is founded on compressible lakebed sediments of the Great Salt Lake. The recent incident occurred on the south eastern side of the dam. The South Drain canal parallels the embankment along this stretch and is approximately 150 feet downstream of the dam. The reservoir was at approximate elevation 4220 (15 feet below the crest of the dam) when this incident occurred.

On November 13, 2006, the Provo Office Area Manager was notified by the Weber Basin Water Conservancy District (District) management that "serious" seepage was occurring at A.V. Watkins Dam. Reclamation and District personnel immediately went to the dam to evaluate the situation. Approximately 150-200 gal/min of seepage was exiting downstream of the toe of the dam. Erosion of the foundation materials was occurring and had removed 10 to 20 yards of material at the toe of the dam. There were numerous sinkholes, 2 to 5 foot in diameter, located between the toe of the dam and the South Drain canal. The seepage exiting at the surface (causing surface boils) and flowing through the subsurface was draining into the South Drain and was loaded with suspended sediment. There was a small slump in the downstream slope immediately upstream of the largest seepage exit point. The amount of the fine sand at the toe of the dam was estimated at 10-20 cy and about 200-300 cy was located in the South Drain. The slumped embankment was a result of material settling into the foundation voids. Piping of the foundation soils was occurring beneath the dam, and silty, sandy, soils were exiting from sand boils at the dam's downstream toe, flowing into downstream sinkholes and exiting into the South Drain canal located 150 feet downstream and parallel to the dam. There was a high probability of failure of the dam, which could have resulted in the uncontrolled release of the reservoir.

[122] Area Manager, Provo Area Office, Bureau of Reclamation, Provo, Utah, bbarrett@uc.usbr.gov
[123] Geotechnical Engineering Team Leader. Technical Service Center, Denver, CO, USA, mbliss@do.usbr.gov

NOTES

LAKE NEEDWOOD DAM FORENSIC EVALUATION REHABILITATION

Bob Pinciotti, PE[124]
Greg Zamensky, PE[125]
Andy Frank, PE[126]

ABSTRACT

Lake Needwood Dam is designed to discharge the 100-year flood water through the 42-inch diameter principal spillway over the course of 10 days, thereby significantly reducing the level of flooding downstream. It is currently owned and operated by the Maryland-National Capital Parks and Planning Commission (M-NCPPC).

During the week of June 26, 2006, heavy rains resulted in a 23-foot rise of the water level in Lake Needwood. On June 28, M-NCPPC personnel observed uncontrolled, concentrated seepage originating from the downstream left groin area. Further examination revealed soil particles in the discharge water; thus, the potential for piping failure of the embankment was judged significant. As a result, nearly 2,300 downstream residents were evacuated. Emergency operations at the dam ensued, including construction of a reverse filter at the seepage site to minimize potential for continued soil migration, construction of a temporary weir to estimate changes in flow rate, and around-the-clock visual monitoring of the embankment.

M-NCPPC commissioned a study to evaluate potential causes for the observed seepage and to develop remedial measures. The final rehabilitation configuration included a double line grout curtain and new chimney/blanket drain on the downstream slope.

[124] Dams and Reservoirs Team Leader, URS Corporation, Gaithersburg, Maryland, bob_pinciotti@urscorp.com
[125] Dams and Levees Practice Leader, Black & Veatch Corporation, Gaithersburg, Maryland, zamenskyg@bv.com
[126] Project Manager, Maryland-National Capital Parks and Planning Commission, Park Development Division, Silver Spring, Maryland, Andrew.Frank@mncppc-mc.org

NOTES

A CASE HISTORY OF A MAJOR SEEPAGE AND INTERNAL EROSION EVENT AT EAST BRANCH DAM, ELK COUNTY, PENNSYLVANIA

Brian H. Greene, Ph.D., P.G.[127]
James E. Sekela, P.E.[128]

ABSTRACT

East Branch Dam is a Pittsburgh District of the U.S. Army Corps of Engineers dam which nearly failed in 1957, several years after construction. The dam is a zoned embankment 184 feet high and 1,725 feet long. The primary purpose of the dam is flood control; however, it also provides low-water regulation and recreation. In May 1957, muddy water was observed flowing from a rock drain at the downstream toe of the dam by project personnel. Drilling through the dam exposed a void which, led to the order to lower the pool and commence emergency grouting of the embankment. Repairs consisted of filling the void with grout and consolidation grouting of the surrounding area of the foundation and the embankment. A permanent weir was constructed at the toe of the dam, and piezometers were installed in the area of the void. Features of the design and construction that have been identified as possible causes of the 1957 emergency are presented and briefly discussed. This dam safety incident provides valuable lessons related to design, construction, and operation of high hazard dams. It is important to review such incidents to maintain awareness of the potential problems that may be present in many older dams and how they can develop.

The project has been closely monitored since the near-failure incident. Even though evidence of further internal erosion has not reappeared, the fundamental conditions that caused the original problem were not corrected by the 1957 emergency repairs. Consequently, a comprehensive engineering evaluation of East Branch Dam is being planned to determine the current conditions, risks, and potential modes of failure.

East Branch Dam was evaluated in 2006 under the Screening Portfolio Risk Assessment (SPRA) program. The purpose of the program is to identify those dam safety projects in the U.S. Army Corps of Engineers inventory that pose the greatest risk to human life, property, and the environment. East Branch Dam has been classified as urgent and has received priority funding to initiate studies to better define existing conditions and to develop Interim Risk Reduction Measures (IRRMs).

The 1957 seepage incident at East Branch Dam represents an excellent case history that can provide dam designers and operators today with an insight on the mechanisms of internal erosion within an embankment dam and the warning signs, and underscores the need for taking appropriate and prompt action.

---

[127] Acting Chief, Planning and Environmental Branch, 1000 Liberty Avenue, U.S. Army Corps of Engineers, Pittsburgh, Pennsylvania, 15222
[128] Chief, Dam Safety and Hydraulics Design Section, 1000 Liberty Avenue, U.S. Army Corps of Engineers, Pittsburgh, Pennsylvania, 15222

NOTES

USE OF NEXRAD WEATHER RADAR DATA WITH THE STORM PRECIPITATION ANALYSIS SYSTEM (SPAS) TO PROVIDE HIGH SPATIAL RESOLUTION HOURLY RAINFALL ANALYSES FOR RUNOFF MODEL CALIBRATION AND VALIDATION

Edward M. Tomlinson, PhD[129]
Tye W. Parzybok[130]
Douglas M. Hultstrand[2]
William D. Kappel[1]

ABSTRACT

The Storm Precipitation Analysis System (SPAS) is a sophisticated meteorological tool used to characterize the temporal and spatial details of rainfall events. SPAS was designed to produce storm depth-area-duration (DAD) analyses for making objective comparisons of rainfall associated extreme storms in Probable Maximum Precipitation (PMP) studies. Hydrologic runoff model calibrations have been the catalyst to use an abbreviated version of SPAS (referred to as SPAS-lite) to provide storm analyses over much smaller domains (generally <100 sq-mi) without the DAD analysis while providing a limited but sufficient set of deliverables for hydrologic modeling purposes. Like SPAS, SPAS-lite produces high resolution spatial and temporal precipitation information. The results are provided as spatially distributed rainfall (spatial resolution approximately one square kilometer) over sub-basins or the average rainfall over sub-basins. Rainfall amounts can be provided as often as every six minutes but are usually provided hourly.

Hourly rainfall observations are generally limited to a small number of locations, with many basins lacking observational rainfall data within the basin boundaries. Often NEXRAD weather radars provide coverage over these basins but lack reliability for determining rain rates and quantitative rainfall amounts. Techniques have been developed to use NEXRAD data together with rain gauge data both within and in close proximity to basins to determine rainfall distributions within a drainage basin. The computed rainfall fields provide reliable hourly rainfall amounts at locations within the basin. These rainfall amounts are computed using NEXRAD data that is calibrated each hour with the rainfall amounts reported at each of the hourly rain gauge sites.

The spatially distributed rainfall fields are clipped to basin or sub-basin boundaries using GIS. The SPAS results are used for calibration and validation of run-off models for extreme rainfall events. The high spatial and temporal resolution hourly rainfall allows for accurate estimates of rainfall volumes over sub-basins. The increased accuracy of the precipitation analyses has eliminated the need for commonly made assumptions about the precipitation characteristics, thereby greatly improving the precision and reliability of hydrologic runoff model results.

[129] Applied Weather Associates, LLC, PO Box 680, Monument, CO 80132, awaadmin@comcast.net
[130] Metstat, Inc, 4764 Shavano Dr, Windsor, CO 80550, tyep@metstat.com

NOTES

ANALYSIS OF NAMGANG DAM FLOOD CONTROL DURING INTENSIVE RAINFALL IN 2006

Woo-Gu Kim, Ph.D[131]
Jin-Hyeog Park, Ph.D[132]
Eul-Rae Lee, Ph.D[133]

ABSTRACT

The Korean peninsula was seriously affected by heavy rainfall from typhoon and seasonal rain front in June, 2006. The rainy season period of 2006 was 46 days and was 2 weeks longer than usual. And accumulated rainfall was 321~1,244 mm according to area, and average rainfall was 717.3 mm which was 3 times more than usual (262 mm). This rainfall was one of the longest and heaviest on record. The amount of 1.4 billion tons flowed into the Namgang Dam due to the heavy rainfall at that time. And the discharge was implemented as the maximum 3,558 m^3/s (main stream 392 m^3/s, Sacheon Bay 3,166 m^3/s, 16:00 10, July) considering the rainfall condition, dam inflow, restrictions of up-downstream and the safety of the dam. Thus, the flood control was accomplished at the maximum stage of EL. 44.48 m (24:00 10, July) which was 1.52 m lower than the designed flood water level (46 m). The maximum amount of 392 m^3/s and 3,200 m^3/s was discharged to the main downstream of Namgang Dam and Sacheon Bay for 5 hours, respectively. It was considered that flood discharge of 5,900 m^3/s and the stage of 2.62 m at the Jindong station were decreased as a result of flood control of the dam. Therefore, we are trying to make a general introduction on the flood control system of Korea Water Resources Corporation that is managing multi-purpose dams in the whole country and analyze the flood control effect of Namgang Dam that influenced on this flood control time in relation to the heavy rain in July of 2006.

[131]Executive Director, Water Resources Division, K-water, San6-2, Yeonchuk-Dong, Daedeok-Gu, Daejeon, 306-711, Korea. Phone: +82-42-629-0300; Fax: +82-42-629-3489; E-mail: wgkim@kwater.or.kr
[132]Researcher, Water Resources Operations Center, K-water, San6-2, Yeonchuk-Dong, Daedeok-Gu, Daejeon, 306-711, Korea. Phone: +82-42-629-3486; Fax: +82-42-629-3489; E-mail: park5103@kwater.or.kr
[133]Researcher, Water Resources Operations Center, K-water, San6-2, Yeonchuk-Dong, Daedeok-Gu, Daejeon, 306-711, Korea. Phone: +82-42-629-3488; Fax: +82-42-629-3489; E-mail: erlee@kwater.or.kr

NOTES

NEW PMP TEMPORAL DISTRIBUTIONS AND A SIMPLIFIED BREACH METHOD FOR DAMS IN TEXAS

John L. Rutledge, P.E.[134]
Warren Samuelson, P.E.[135]

ABSTRACT

In August 2006, the Texas Commission on Environmental Quality (TCEQ) released new guidelines that provide instructions, standards, and accepted procedures for the hydrologic and hydraulic analysis of existing and proposed dams in the Texas. The guidelines, in defining procedures for developing design flood estimates and performing breach analyses, serve to document and clarify the expectations of TCEQ with respect to submitted analyses and to simplify the review procedure by standardizing processes and elements that will be acceptable to TCEQ. Many of the procedures outlined document well established methodologies of the industry. However, the guidelines also provide for two new procedures, a new temporal distribution of the Probable Maximum Precipitation (PMP) and a Simplified Breach Method that were developed specifically for the new guidelines. The paper presents a detailed discussion of the theoretical and empirical background and support that led to the new procedures. The new PMP temporal distribution incorporates more recent accumulated knowledge about extreme rainfall events and utilizes assumptions that vary from the more conservative approaches of HMR52 and NRCS procedures, but are more consistent with historical data. The paper also demonstrates the impact of the new guidelines by comparing results of several Design Flood determinations made using the new guidelines with those made using previous standards. The simplified breach method is a purely empirical procedure that is intended to reduce costs associated with compliance with state dam safety rules by simplifying breach analyses calculations for smaller dams with approximate, yet conservative methods.

These guidelines were prepared by Freese and Nichols under the direction of the Dam Safety Program of the TCEQ.

[134] Principal and Vice President, Freese and Nichols, Inc.; 4055 International Plaza, Suite 200, Fort Worth, Texas 76109; jlr@freese.com
[135] Dam Safety Program Coordinator, Texas Commission on Environmental Quality; PO Box 13087 MC-174, Austin, Texas 78711-3087; wsamuels@tceq.state.tx.us

NOTES

FERC DAM SECURITY PROGRAM UPDATE

Frank Calcagno[136]

ABSTRACT*

Six years have passed since the attacks of 9/11. In that time, great progress has been made in many areas. The FERC, in consultation with a collaborative work group of FERC staff and Licensees, issued the Security Program for Hydropower Projects on June 2002, with Revision 1 dated November 11, 2002. Through that time, the FERC has hosted annual security workshops to provide informational updates to Licensees and the US dam community. The Department of Homeland Security established coordinating councils of federal/state and private dam owners, and FERC developed the Dam Assessment Matrix for Security and Vulnerability Risk (DAMSVR). From the knowledge gained from these efforts, and the professional staff of the hydropower utilities, FERC Licensees have made tremendous progress strengthening their on-site security and response procedures.

A second revision to the FERC Security Program is nearing completion and will soon be available for comment. Some of the proposed changes involve the need to update security documents, exercising security plans, and defining how the FERC staff document the results of their inspections.

Immediately following 9/11, most federal and private dam owners prioritized their dams based on consequence only; however, many organizations are now turning to a more risk-based prioritization process. FERC has used the results of over 1,000 DAMSVR assessments of jurisdictional projects to re-categorize their dams into a revised Security Grouping, using consequence, vulnerability and accessibility, resulting in some alterations to the Group 1, 2, and 3 categorizations of jurisdictional dams.

[136] Federal Energy Regulatory Commission, 888 First Street, NE, Washington, DC 20426, Telephone: 202-502-6025, E-mail: frank.calcagno@ferc.gov

*This paper is not included in the Conference Proceedings CD.

NOTES

HR BREACH: DEVELOPING A PRACTICAL BREACH MODEL TO MEET INDUSTRY NEEDS

Mark Morris[137]
Mohamed Hassan[138]
Yves Buchholzer[139]
Tom Davies[140]

ABSTRACT

The accurate and reliable prediction of breach formation through a flood embankment or an embankment dam is a difficult task, yet this performs an essential role in many aspects of flood risk management. Different users of breach information may include embankment and dam designers, asset managers, emergency planners, emergency repair workers etc. each of whom place emphasis on different aspects of the breach prediction, such as the time before catastrophic failure, peak discharge, size of breach or volume of flood water released. With such a range of flood risk management activities dependent upon breach model prediction, it is important that we provide usable and effective models for accurately predicting the entire breaching process.

HR Wallingford started research into the development of a new breach model in 1998, when the need for a model that reflected real breach processes for a range of situations was identified. The HR BREACH model was developed in 2002 and has been the focus for refinement and continued development since then. This research and development work has pulled together state of the art knowledge and expertise from the UK, Europe and the US. The HR BREACH model predicts growth of a breach arising from piping or overflow through cohesive and non cohesive materials. It combines hydraulics, sediment erosion and discrete embankment stability analyses into the prediction of breach, allowing the 'free' formation of breach shape through the embankment or dam. The model also permits the use of parameter ranges, rather than specific values, supporting Monte Carlo analysis for predicting breach growth.

This paper first provides a brief overview of the current state of the art, drawing from European and US initiatives, such as European projects FLOODsite and IMPACT, and US initiatives such as the Dam Safety Interest Group breach. Recent developments in the HR BREACH model are then highlighted, including practical considerations of how end user application, computing power, model speed and accuracy all contribute towards the balanced development of this modelling tool. Finally, details are given as to the future direction for model development and availability, which are aimed to meet recognised gaps in existing knowledge and modelling capability.

[137] Principal Engineer, HR Wallingford Ltd., Howbery Park, Wallingford, Oxfordshire, OX10 8BA, UK, m.morris@hrwallingford.co.uk
[138] Senior Engineer, HR Wallingford Ltd., Howbery Park, Wallingford, Oxfordshire, OX10 8BA, UK, mam@hrwallingford.co.uk
[139] Researcher, Ecole Centrale de Lyon, France, ybuchhol@ec-lyon.fr
[140] CEO, Wallingford Software Inc., US. tdavies@wallingfordsoftware.com

NOTES

DEVELOPMENT OF NEXT-GENERATION EMBANKMENT DAM BREACH MODELS

Tony L. Wahl[141]
Gregory J. Hanson[142]
Jean-Robert Courivaud[143]
Mark W. Morris[144]
René Kahawita[145]
Jeffrey T. McClenathan[146]
D. Michael Gee[147]

ABSTRACT

The Dam Safety Interest Group (DSIG) of CEA Technologies, Inc. (CEATI) is an international group of dam owners that pursues collaborative research on a wide range of topics. Since 2004 the DSIG has been working to facilitate the development and deployment of a physically-based embankment dam breach model. The group, with assistance from non-CEATI member organizations, has completed a first phase of work which identified promising numerical models presently under development and compiled real-world case study data and large-scale laboratory test data for future use in model validation. In the second phase of the project, the group will evaluate candidate modeling technologies using the assembled data sets and then integrate selected technologies into the HEC-RAS dynamic routing model suite. Parallel work is also underway to evaluate methods for quantifying the erodibility of embankment materials, a key input for a new and improved model. At this time, the models under consideration are primarily capable of analyzing embankments with simple geometries experiencing overtopping flow. In a future third phase, the group plans to pursue capabilities for more complex and varied embankment configurations and for breaches initiated by internal erosion and piping.

[141] Hydraulic Engineer, U.S. Department of the Interior, Bureau of Reclamation, Denver, CO 80225. twahl@do.usbr.gov
[142] Research Hydraulic Engineer, USDA-ARS Hydraulic Engineering Research Unit, Stillwater, OK 74075, greg.hanson@ars.usda.gov
[143] Hydraulic Engineer, Electricité de France, Chambéry, France, jean-robert.courivaud@edf.fr
[144] Hydraulic Engineer and Project Manager, HR Wallingford, Wallingford, UK, m.morris@hrwallingford.co.uk
[145] Professor, École Polytechnique de Montréal, Montréal, QB Canada, rene.kahawita@polymtl.ca
[146] Chief, Hydraulic Section, U.S. Army Corps of Engineers, Omaha, NE, Jeffrey.T.McClenathan@usace.army.mil
[147] Senior Hydraulic Engineer, U.S. Army Corps of Engineers, Davis, CA, Michael.Gee@hec01.usace.army.mil

NOTES

RESULTS FROM OVERWASH TESTING ON EARTHFILL EMBANKMENTS IN SOUTH FLORIDA

Bruce A. Phillips, P.E.[148]
Becky J. Hachenburg, P.E.[149]
Jeffrey R. Kivett, P.E.[150]

ABSTRACT

Design and construction of the Comprehensive Everglades Restoration Program (CERP), the world's largest environmental restoration program, is underway in South Florida. A key part of the program is the construction of three major above-ground reservoirs. In total, the reservoirs require over 47 miles of embankment with storage ranging from 50,000 to 190,000 acre-feet. With the combination of unique geology, construction materials and hurricane events, over-wash is an important consideration for dam safety. Significant wave heights can develop in shallow reservoirs with long fetch distances. Literature research shows some general guidelines for over-wash rates. However, the guidelines are general (e.g. over-wash should not be of such a magnitude and duration as to threaten the safety of the dam), and without any quantification.

CERP impoundments will be shallow and have fetch lengths up to 8 miles. Interpretation of the freeboard height can vary by several feet depending on the over-wash rate selected for design. At a cost as high as $ 8 million per foot of height for the larger reservoirs, the selection of an appropriate over-wash rate has major implications.

As part of CERP, the South Florida Water Management District (SFWMD) has constructed prototype test cells at each of the proposed reservoir locations. A major benefit of the test cell program was the ability to conduct full-scale overwash tests on prototype embankment sections. To help in the selection of the appropriate overwash rate, the SFWMD utilized their test cell program to observe actual performance of the embankments' downstream slope under various over-wash scenarios.

The overwash testing program provides important new data on erosion of embankments constructed with cohesionless material. Results from the field tests will provide important new information for the evaluation and design of embankments.

[148] Construction Manager, MWH Americas, Inc., 2301 Centrepark West, Suite 150, West Palm Beach, FL 33409, bruce.a.phillips@mwhglobal.com
[149] Technical Services Manager, MWH Americas, Inc., 2301 Centrepark West, Suite 150, West Palm Beach, FL 33409, becky.j.hachenburg@mwhglobal.com
[150] Director of Engineering, Everglades Restoration, South Florida Water Management District, 2301 Centrepark West, Suite 150, West palm beach, FL 33409, jkivett@sfwmd.gov

NOTES

PRACTICAL APPLICATION OF RESEARCH RELATED TO HIGH VELOCITY FLOWS OVER OPEN OFFSET JOINTS IN SPILLWAYS

John Trojanowski, P.E.[151]

ABSTRACT

This paper will describe how research related to high velocity flows over open offset joints is used in the U.S. Bureau of Reclamation's dam safety program. This condition has led to damage or failure of spillway chutes due to increased uplift and/or flow into spillway foundations. This paper will include discussions related to evaluation existing conditions; identifying the potential to develop this failure mode at spillway joints; and evaluation of risk. Issues related to high velocity flows over open joints has been known for some time, but adequate tools for assessing risk associated with this condition have not been available. Reclamation has been working to develop tools to identify and correct this potential problem before it progresses to a significant dam safety incident. Recent hydraulic laboratory research [1] has been conducted to provide a better understanding of failure mechanisms. This paper will include a discussion on the use of this information in evaluating spillways.

[151] Civil Engineer, Waterways & Concrete Dams, Bureau of Reclamation, Denver, CO
jtrojanowski@do.usbr.gov

NOTES

A LABYRINTH RISES IN THE HEART OF TEXAS

Victor M. Vasquez, P.E.[152]
M. Leslie Boyd, P.E.[153]
John S. Wolfhope, P.E.[154]
Ricky Garrett, P.E.[155]

ABSTRACT

The Lake Brazos Dam in Waco, Texas, was completed in 1970 as a gated spillway. The spillway was converted to a labyrinth weir structure in 2006/2007 to eliminate operational and maintenance problems which historically plagued the spillway gates. The labyrinth design was developed following extensive hydrologic and hydraulic analysis of the Brazos River. Physical models of various labyrinth weirs were built, and in conjunction with the river data, tested to assess long term labyrinth performance and construction restrictions. Besides hydraulic performance, the testing provided valuable insight into possible construction sequences and risk associated with river floods. Ultimately, the project addressed the hydraulic challenges and successfully accommodated local requirements regarding lake levels and project cost.

The 3,000-foot long labyrinth weir was constructed within the footprint of the existing dam to accommodate regulatory requirements and to reduce cost. The construction was performed in phases to manage normal river flows and potential flooding and to eliminate costly river diversions. Sections of the permanent sheetpile cut-off and the existing gates were used as cofferdams to protect work areas and maintain a full reservoir during construction. Strict tolerances for wall height, crest profiles, and concrete finish were required to satisfy special requirements for hydraulic performance and aesthetics. The project also included demolition, extensive foundation work, riprap installation, and a significant amount of reinforced concrete. The labyrinth weir construction was performed under both advantageous river conditions due to a drought and adverse river conditions due to severe weather and flooding. During construction in 2007, flooding on the Brazos River provided the first test of the labyrinth weir, and it performed successfully. With the challenges met, the City looks forward to an attractive and reliable reservoir.

[152] Lead and Resident Engineer, Freese and Nichols, Inc., 10814 Jollyville Rd., Bldg 4, Ste. 100, Austin, TX 78759, vmv@freese.com
[153] Associate, Freese and Nichols, Inc., 10814 Jollyville Rd., Bldg 4, Ste. 100, Austin, TX 78759, mlb@freese.com
[154] Principal and Project Manager, Freese and Nichols, Inc., 10814 Jollyville Rd., Bldg 4, Ste. 100, Austin, TX 78759, email: jsw@freese.com
[155] Director of Water Utilities, City of Waco, 200 Colcord, Building 100, Waco, TX 76707, RickyG@ci.waco.tx.us

NOTES

EVALUATION OF EXISTING DAMS FOR OVERTOPPING FAILURE MODE BASED ON RISK CONSIDERATIONS

William R. Fiedler, P.E.[156]
John F. England, Jr. P.E.[157]
John H. LaBoon, P.E.[158]

ABSTRACT

Failure of a dam due to overtopping during a major flood is a common potential failure mode considered for most dams. The Bureau of Reclamation (Reclamation) has developed a systematic approach to evaluate dams for this potential failure mode. Dams are initially screened on their ability to pass the Probable Maximum Flood (PMF), which is defined as the most extreme hydrologic loading that is conceivable for a given drainage basin. If a given dam can safely pass the PMF, overtopping risks are considered to be below Reclamation's Public Protection Guidelines. If a dam can not safely pass the PMF, a flood frequency study is conducted to determine the flood level at which overtopping initiates. Hydrographs of critical frequency floods may be developed as part of the study. Using this information, risks are estimated for various flood load ranges and then summed to determine the overall risk of an overtopping failure. If the risk is high enough, additional action is taken to reduce risk for this potential failure mode, which may include modifications to increase the spillway discharge capacity or raise the dam. Routings of flood frequency hydrographs and risk estimates are performed to identify the design level needed to achieve acceptable risk reduction for an overtopping failure mode. This paper describes the process used by Reclamation to evaluate dams for an overtopping failure mode.

[156] William R. Fiedler, Civil Engineer, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, bfiedler@do.usbr.gov
[157] John F. England, Jr. Hydraulic Engineer, Bureau of Reclamation, PO Box 25007, 86-68530, Denver, CO 80225, jengland@do.usbr.gov
[158] John H. LaBoon, Supervisory Civil Engineer, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, jlaboon@do.usbr.gov

NOTES

DEVELOPING AND COMMUNICATING COST UNCERTAINTY AND COST RISKS FOR A LARGE MULTI-YEAR WATER RESOURCES PROJECT

Nathan Snorteland[159]
Daniel Maag[160]

ABSTRACT

The U.S. Bureau of Reclamation's Folsom Facility is currently being modified to reduce risks associated with seismic, hydrologic, and internal erosion deficiencies. The Corps of Engineers is also constructing improvements to the facility to reduce potential flood damages in the Sacramento metropolitan area. Reclamation's portion of the construction may take as long as 14 years to complete and has an anticipated cost of $520 Million. In the planning and approval stages, the project's anticipated cost and duration forced Reclamation to develop new cost estimating strategies to communicate the uncertainties and risks associated with the official cost estimate forwarded to the Office of Management and Budget and to Congress. The foundation for these strategies was set by modifying Reclamation's standard approaches to cost estimating by explicitly developing quantity and unit price uncertainties. The process was augmented by analyzing the effects of restricting factors such as air quality ceilings, available funding, inflation, procurement strategies, and physical constraints. The product of these studies was a group of cost distributions for each bid item, potential contract package, non-contract item, total field cost, and total project cost. These distributions formed the basis to effectively communicate to management the primary sources of cost risks and total project cost uncertainty. This paper will examine the process Reclamation used to quantify the cost uncertainties and risks and how this information was synthesized and presented to management to facilitate the selection of a total project cost.

[159] Program Manager, Dam Safety Office, U.S. Bureau of Reclamation, nsnorteland@do.usbr.gov, P.O. Box 25007,Denver, CO 80225
[160] Senior Civil Engineer, Estimating, Specifications, and Value Program Group, Technical Services Center, U.S. Bureau of Reclamation, dmaag@do.usbr.gov, P.O. Box 25007, Denver, CO 80225

NOTES

ALTERNATIVE PROJECT DELIVERY METHODS FOR DAM CONSTRUCTION AND REHABILITATION

Daniel J. Hertel, P.E.[161]
Daniel L. Johnson, P.E.[162]
William R. Fiedler, P.E.[163]
Dietmar Scheel, P.E.[164]

ABSTRACT

Alternative project delivery methods, such as Design-Build and CM@Risk, are increasing in popularity throughout the engineering and construction industries. Under the right circumstances, and when performed correctly, they offer owners, engineers, and contractors significant advantages in schedule, budget and flexibility. While many in the heavy-civil arena have embraced these methods, the dams and water resources community has been slower than our peers to use them. The complex nature of these projects, the large contract values, the public safety issues, the high degree of variables, and the lack of significant alternative contracting examples all contribute to this situation. Yet, a number of dam projects have been completed under these contracting methods and the lessons learned from these projects are beginning to shed light on the aspects that make for a successful alternative delivery project. This paper explores current alternative delivery methods of contracting; reviews what may drive a decision to use them as well as the filters that acknowledge some limitations; and briefly discusses the merits of each delivery method. Two example projects are highlighted at the end of the paper.

[161] Vice President, Barnard Construction Co., Inc., P.O. Box 99, Bozeman, MT 59771, dan.hertel@barnard-inc.com
[162] Vice President, GEI Consultants, 1790 38th Street, Suite 104, Boulder, CO 80301, dljohnson@geiconsultants.com
[163] Civil Engineer, Bureau of Reclamation, P.O. Box 25007, 86-68130, Denver, CO 80225, bfielder@do.usbr.gov
[164] Sr. Construction Contracts Engineer, MWH Americas, Inc., 175 West Jackson Blvd., Chicago, IL 60604, dietmar.scheel@us.mwhglobal.com

NOTES

LESSONS LEARNED FROM CONSTRUCTION OF PROTOTYPE EMBANKMENT DAMS IN SOUTH FLORIDA

Gregory A. Hillebrenner, P.E.[165]
Bruce A. Phillips, P.E.[166]
Jeffrey R. Kivett, P.E.[167]

ABSTRACT

The South Florida Water Management District (SFWMD), in partnership with the Corps of Engineers, is constructing several projects as part of the Comprehensive Everglades Restoration Program (CERP) to improve the Everglades eco-system. Three of the projects include above-ground water storage reservoirs, created by earthen embankment dams ranging from 9 to 22 miles long, with water depths of 12.5 to 25 feet and impoundment areas of 3,400 to 15,100 acres. The reservoirs will be used to improve the timing, quality, quantity and distribution of critical water supplies for environmental restoration.

Historically, embankment construction in the region has been for levees providing flood control and conveyance, and not for permanent water storage. Hurricane Katrina exposed concerns with earthen embankments in coastal regions and required engineers and dam owners to re-evaluate the assumptions used for design and long-term performance.

The SFWMD has constructed prototype 500-foot by 500-foot test cells of alternative embankment sections to evaluate their performance, and to site-specifically determine cost-effective embankment sections, seepage control measures and construction procedures. Lessons learned from the prototype test cells ($8.5-$10 million per site) have far exceeded the expectations and significantly reduced the risks associated with the design and construction of these reservoirs and have provided invaluable information for design engineers to apply to these and other future reservoirs in Florida.

[165] Senior Project Manager. MWH Americas, Inc., 2301 Centrepark West, Suite 150, West Palm Beach, FL 33409, gregory.a.hillebrenner@mwhglobal.com
[166] Construction Manager, MWH Americas, Inc., 2301 Centrepark West, Suite 150, West Palm Beach, FL 33409, bruce.a.phillips@mwhglobal.com
[167] Director of Engineering, Everglades Restoration, South Florida Water Management District, 2301 Centrepark West, Suite 150, West Palm Beach, FL 33409, jkivett@sfwmd.gov

NOTES

GEOTEXTILES IN DAMS — FORGING FEDERAL GUIDELINES

Douglas A. Crum[168]

ABSTRACT

The major dam building era for large dams in the United States during the 1940's to the 1970's ended about the time geotextiles were becoming popular. For the last 40+ years, geotextiles have been used in many dams worldwide for various applications. During this period, federal agencies have resisted experimentation with geotextiles in critical applications, agency policy has been to generally restrict use, and there have been minimal criteria governing use in federally funded water resource projects. Geotextiles have been used for various purposes on levees and dams, sometimes (by some interpretations) against agency policy. Geotextiles are often recognized to provide economical solutions. In some cases, geotextiles have been reported to provide the only viable solution, which can be especially useful in remediation of existing structures. Current projections are for increasing, perhaps explosive growth in rehabilitation of levees and dams. With the current geosynthetic industry experience, it is increasingly compelling to formulate criteria that encourage general use of geotextiles while preventing misuse. Even within high hazard structures, there exist non-critical applications such as landscaping fabrics or those that promote longevity of pavements. On the other spectrum, internal filters for large dams are a critical application and a controversial issue. The federal approach for utilization of geotextiles should not condone use through absence of criteria. Compromise solutions based on technical merit alone are not adequate to resolve restrictions governing geotextile use. For critical applications, criteria must be based on design resiliency and risk tolerance. A perspective will be offered concerning pragmatic use of geotextiles for water resource projects, especially in critical applications and high hazard structures.

[168] Dam Safety Program Manager, U. S. Army Corps of Engineers -Kansas City District, Kansas City, MO 64106, douglas.a.crum@usace.army.mil

NOTES

WHITE RIVER PROJECT, DIKE 14/15 BACKFLOW PREVENTION STRUCTURE

Steve Benson[169]
Rahim Nasserziayee[170]
Frank Hella[171]

ABSTRACT

The Puget Sound Energy's (PSE's) White River Project, Printz Basin, located near Bonney Lake, Washington, is one of several major components of the flow line system that delivers water to Lake Tapps from a diversion dam on the White River near Buckley, Washington , refer to Exhibit 1. The basin is formed by two parallel dikes (Nos. 14 and 15), approximately 1,000 feet apart, each 1,500 feet in length and about 30 feet high. Regional and local geologic information indicates the dikes are founded on loose mudflow materials. Geotechnical and seismic analysis have indicated the dikes and/or their foundations may be subject to liquefaction during a Maximum Credible Earthquake (MCE) event. This paper contains information about the design and construction of a backflow prevention structure (BPS) that will limit the risk of flooding of the low lying lands and properties due to the possible failure of dikes 14/15 during an MCE event.

[169] Manager Geotechnical/Consulting Department, URS, Washington Division, 10900 N.E. 8th Street, Suite 500, Bellevue, WA 98004, stephen.benson@wgint.com
[170] Consulting Engineer, URS, Washington Division, 10900 N.E. 8th Street, Suite 500, Bellevue, WA 98004, rahim.nasserziayee@wgint.com
[171] Program Manager, Safety & Emergency Response Energy Resources, Puget Sound Energy, 10885 N.E. 4th Street, PSe-095, Bellevue, WA 98004, frank.hella@pse.com

NOTES

PERFORMANCE OF THE RALSTON DAM SPILLWAY

Gokhan Inci[172]
Michael J. Miller[173]

ABSTRACT

Stability problems with dam spillways on existing landslides and appropriate mitigation measures to remedy them are ongoing concerns for geotechnical engineers. The first successful application of drilled piers as stabilizing structures under the spillway was at the Trinity Dam in Sicily, Italy. "Underpinning" was considered as an alternative to spillway relocation during the Alpaslan 2 embankment dam design in eastern Turkey. Based on the available literature the first application of drilled piers to stabilize a spillway chute in the U.S. was at the Ralston Dam in Colorado.

Ralston Dam, which is a 175-foot-high zoned fill dam located 15 miles northwest of downtown Denver, was built in the late 1930s. The concrete spillway for the dam was built on the Pierre Shale Formation in the left abutment. Since reservoir operations began, mass movements have occurred downstream of the chute area. These movements have required periodic spillway maintenance. After the occurrence of recent movements and because of high piezometeric levels, URS was contracted by Denver Water to develop a more permanent solution by the installation and monitoring of additional instrumentation, analysis of slope stabilizing measures, design, repair, and reconstruction of the distressed section of the spillway chute. With state of the art modifications that include: 1) a stabilizing berm with a toe trench that improves the global stability; 2) seepage prevention and control measures that prevent the infiltration of water; and 3) the structural support of the replaced chute section with drilled piers and reinforced concrete the probability of future displacements or other problems have been reduced for the Ralston Dam Spillway. Over the last two years Ralston Dam spillway performed without any problems.

[172] Senior Project Engineer, URS Corporation, 8181 E. Tufts Ave., Denver, CO 80237
[173] Engineering Manager, Dam Safety Engineer V, Denver Water, 1600 W. 12th Ave., Denver, CO 80204.

NOTES

SPILLWAY GATE ISOLATION USING SEGMENTAL FLOATING BULKHEADS

Frederick Lux III [174]

ABSTRACT*

The concept of a segmental floating bulkhead is to break a one-piece floating bulkhead used to isolate spillway gates into a series of horizontal logs, tubes or caissons. This action overcomes many of the shortcomings of a one-piece floating bulkhead that limit its application. Each caisson is floated individually on the reservoir, secured together by various means and then installed across the spillway or intake opening to be dewatered. In the past 20 years, the Tulsa District of the US Army Corps of Engineers, Ayres Associates, and Aubian Engineering have conceived and developed different segmental floating bulkheads for isolating gated passages. In developing and using the segmental floating bulkhead, these entities discovered several other benefits for its use in dewatering openings.

The focus of this presentation will be to describe the development of three types of segmental floating bulkheads, list their common advantages over one-piece floating bulkheads and other dewatering means, and contrast the fabrication and operation methods between the three bulkheads. The three segmental bulkhead types use a different fabrication means to build an essentially hollow tube. Various aspects of fabrication can limit the usefulness of the segmental floating bulkhead with regards to available sizes, operation flexibility, availability of materials, fabrication difficulties and corrosion protection. Also, these segmental floating bulkheads use several methods for installation and removal: stacking, “hinged” or “garage-door”, and “single-panel.” Each method has its advantages and disadvantages that will be discussed.

[174] Senior Associate, Schnabel Engineering, LLC, 11-A Oak Branch Drive, Greensboro, NC 27407, flux@schnabel-eng.com

*This paper is not included in the Conference Proceedings CD.

NOTES

DETECTING VOIDS BEHIND CONDUITS USING ACOUSTIC TECHNOLOGY

Fred A. Travers[175]
William F. Kepler[176]

ABSTRACT

The presence of voids in the fill around conduits through embankments is a recognized problem. Detection and location of these voids is difficult until a void becomes so large that the integrity of the structure is at risk. A research effort has been mounted to explore the viability of using acoustic technology to detect such voids before they imperil the embankment. Using a technique similar to tapping on a wall and listening to the sound to locate a stud, a system has been developed that taps on the inside of a pipe and records the sound made while it moves through the pipeline. An automated analysis of the recorded sounds has shown potential as a means of detecting and locating voids.

[175] Electronics Engineer, Materials Engineering and Research Laboratory, Bureau of Reclamation, Denver, CO 80225, ftravers@do.usbr.gov
[176] Group Manager, Materials Engineering and Research Laboratory, Bureau of Reclamation, Denver, CO 80225, wkepler@do.usbr.gov

NOTES

MANAGING DAM SAFETY RISKS THROUGH SURVEILLANCE AND MONITORING PLANS AND SURVEILLANCE AND MONITORING REPORTS

Patrick J. Regan[177]
Justin D. Nettle, P.E.[178]
John A. Zygaj, P.E.[179]

ABSTRACT

A key component of a comprehensive dam safety program is the owner's Surveillance and Monitoring Plan (SMP) that includes policies and procedures to assure the data obtained is accurate and evaluated in a timely manner, anomalies are thoroughly investigated and appropriate actions are taken in the event the data indicates the dam is behaving in an adverse manner.

Steps critical to this effort include:

- Identifying potential failure modes (PFMs);
- Installing appropriate surveillance and/or monitoring systems to detect the development of the identified PFMs;
- Identifying action levels;
- Developing and implementing policies and procedures for obtaining data in a timely and accurate manner;
- Developing and implementing policies and procedures to assure the data is evaluated in a timely manner; and
- Developing an Emergency Action Plan (EAP) that addresses the steps to be taken in the event an action level is exceeded.

The FERC's Dam Safety Performance Monitoring Program provides guidance on performing a Potential Failure Modes Analysis and requirements for a Surveillance and Monitoring Plan.

This paper discusses the importance of Surveillance and Monitoring Plans and Reports in managing the risks associated with dams and specific guidance developed by the FERC.

[177]Regional Engineer, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, 805 SW Broadway, Suite 550, Portland, OR, 97205, Patrick.Regan@FERC.gov
[178]Civil Engineer, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, 805 SW Broadway, Suite 550, Portland, OR, 97205, Justin.Nettle@FERC.gov
[179]Supervisor – Dam Safety Engineering, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, 230 South Dearborn, Room 3130, Chicago, IL, 60604, John.Zygaj@FERC.gov

NOTES

PUMPED STORAGE TECHNICAL GUIDANCE

Warren A. Witt[180]
Ernest D. Brockman, Jr.[181]
David W. Lord[182]

ABSTRACT*

After the Taum Sauk Dam failure, two meetings were held between the Federal Energy Regulatory Commission (FERC) and pumped storage hydro-electric project owners. The first meeting was to discuss fault tree evaluations of the overtopping protection schemes for the projects. The second was to develop technical guidance for pumped storage owners. A technical guidance document has been developed by the group which provides criteria for project owners to assess their facilities and programs against. The document specifically focuses on water level control and management. Over pumping is the principal feature that sets pumped storage projects apart from conventional hydro projects and overtopping is the principal failure mode that could impact dam and public safety.

Every pumped storage project has very unique design features, and thus the document is meant to encompass all projects and to allow the owners to choose those parts of the guidance applicable to their projects. The document has been divided into three main sections: Design Basis, Organization Processes, and Instrumentation and Monitoring Equipment. These three sections were chosen by the group as the main issues raised by the Taum Sauk failure and of potential benefit to owners of Pumped Storage projects.

[180] Ameren UE, Manager of Hydro Operations, 573-365-9322, wawitt@ameren.com
[181] Duke Energy, 704-382-8588, EDBrockman@duke-energy.com
[182] Federal Energy Regulatory Commission, Office of Energy Projects, Division of Dam Safety and Inspections, Portland Regional Office, 503-552-2728, david.lord@ferc.gov
*This paper is not included in the Conference Proceedings CD.

NOTES

GEOTECHNICAL ANALYSIS AND INSTRUMENTATION MONITORING DURING THE DRAW-DOWN AND REWATERING OF THE BLENHEIM-GILBOA PUMPED STORAGE POWER PROJECT

Chad W. Cox, P.E.[183]
Fan Xi, P.E. Ph.D.[184]
Alton P. Davis, Jr., P.E.[185]
Robert Knowlton, P.E.[186]
William H. Hover, P.E.[187]

ABSTRACT

The New York Power Authority (NYPA) is in the process of a Life Extension / Modernization (LEM) project at its Blenheim-Gilboa Pumped Storage Power Project (B-G) in upstate New York. Work on this project required the Upper Reservoir to be drained and the penstocks, power tunnel, and 1,143-foot deep shaft to be dewatered for the first time since original construction over thirty years ago. Prior to the work, NYPA and their consultants investigated the potential consequences of such a dewatering. The primary risk identified was the potential for steel penstock liner buckling due to unbalanced external hydrostatic pressures.

GZA GeoEnvironmental of New York (GZANY) recommended to NYPA that subsurface geotechnical instrumentation be installed to monitor groundwater pressure prior to and during the critical de-watering period. Fortunately, NYPA had engaged a member of the original project design team as a part of the Board of Consultants for the LEM project. On the basis of his extensive knowledge of the investigations, design, and construction of the project, Mr. Alton P. Davis, Jr. pointed out the potential existence of two original monitoring wells located on the penstock alignment. These wells (up to 750 feet deep) were later found, cleaned, and fitted with modern instrumentation. Data from these wells, combined with analytical studies, provided NYPA with the confidence to move forward with the Upper Reservoir drawdown and penstock de-watering. NYPA's use of an engineer with prior project experience as an independent consultant provided added value to the project and allowed his knowledge to be transmitted to a new generation of owner staff and their engineers.

The first two of four planned LEM dewatering cycles were successfully completed in 2006 and 2007. No evidence of penstock buckling or distress has been observed to date.

---

[183] Senior Project Manger, GZA GeoEnvironmental, Inc. One Edgewater Drive, Norwood, MA 02062. Ph: (781) 278-5787 Fax: (781) 278-5701 chad.cox@gza.com

[184] Formerly: Lead Engineer, New York Power Authority. Now: Engineering Manager, Geotechnical Services, Tectonic, 70 Pleasant Hill Rd., Mountainville, NY 10953, FXi@tectonicengineering.com

[185] President, Alton P. Davis, Jr. Engineering Consulting Inc., 12 Old Mill Road, PO Box 223, West Ossipee, NH 03890. Ph: (603) 539-8010 Fax: (603) 539-4697 apdavis@localnet.com

[186] Director - Civil/Structural Engineering, New York Power Authority. 123 Main St., White Plains, NY 10601. Ph: (914) 681-6424 Fax: (914) 681-6534 Robert.Knowlton@nypa.gov

[187] Senior Principal, GZA GeoEnvironmental, Inc. One Edgewater Drive, Norwood, MA 02062. Ph: (781) 278-3816 Fax: (781) 278-5701 william.hover@gza.com

NOTES

PROVIDING IMPROVED DAM SAFETY MONITORING USING EXISTING STAFF RESOURCES: FERN RIDGE DAM CASE STUDY

Barry K. Myers, P.E.[188]
David H. Scofield, P.E., C.E.G.[189]

ABSTRACT

The need for automated performance monitoring systems is increasing as the personnel resources available for dam safety monitoring remains limited. A properly designed and implemented automated monitoring system can save labor and improve the quality of the data and the dam owner's ability to detect a developing safety condition.

The U.S. Army Corps of Engineers, Portland District (Corps) recently completed a project to enhance long-term dam safety monitoring of Fern Ridge Dam by installing new instruments and a new automated data acquisition system (ADAS). The dam is a rolled earth embankment structure that is located approximately 12 miles northwest of the city of Eugene, Oregon on the Long Tom River. The embankment internal drainage system began failing and was replaced. As a result of the reconstruction of the embankment, the previously installed instruments were removed or destroyed during excavation and were replaced during the embankment rebuilding. Because of the large number of instruments involved in monitoring the seepage performance at multiple cross sections along the 6610 foot long crest, an ADAS was implemented.

The ADAS was integrated with the Corps' existing dam safety database to provide for fully automated collection, reduction, and presentation of the data. The objective of fully automating the system was to reduce the manpower required for monitoring, reduce safety hazard associated with manually accessing weirs located within confined spaces, and to improve the quality and consistency of the data. The dam safety monitoring system also includes an interface that provides real time feedback of the seepage performance to operations personnel who are located off site.

This paper discusses the new Fern Ridge Dam monitoring program, the role of the instrumentation in monitoring long-term seepage performance, why automated monitoring was used, and how the system was designed and implemented to reduce the manpower required for monitoring. Discussions of how the monitoring results are used to make decisions regarding the continued safe operations of the project are also provided.

---

[1]President, Engineered Monitoring Solutions, 20345 S.W. Pacific Hwy, Suite 104, Sherwood, OR 97140
[2]Geotechnical, Civil and Environmental Design Section, U.S. Army Corps of Engineers, Portland District, 333 SW First Avenue, Portland, OR 97204

NOTES

SEEPAGE ANALYSIS AT WOLF CREEK DAM: STUDYING THE DIAGNOSTIC EFFECTIVENESS OF AUDIO FREQUENCY DOMAIN MAGNETICS IN KARST ENVIRONMENTS

Val Kofoed[190]
Paul Rollins[191]

ABSTRACT

As part of an ongoing rehabilitation effort at Wolf Creek Dam, a sixty-year old structure on the Cumberland River, the US Army Corps of Engineers Nashville District recently employed a new seepage-diagnosis tool that uses Controlled Source - Audio Frequency Domain Magnetics (CS- AFDM). In this procedure, electrodes are strategically placed on the up and downstream sides of an earthen embankment dam. When the electrodes are charged, the electrical current gathers in areas of highest water concentration while emitting a distinctive magnetic field (Biot-Savart Law). That field is then captured by a specially tuned receiver, and the received data is used to generate both two-dimensional maps and three-dimensional models of the water flow in the surrounding area. The maps and models show where the dam may be compromised by developing seeps. If seepage is detected, these resources provide remediation teams with the information necessary to begin stemming the water flow.

This technology carries great promise. By using electrical currents and magnetic fields—rather than drawing down reservoirs or drilling—to analyze the seepage paths, CS-AFDM procedures can avoid much of the disruption and delay entailed in more traditional analytical techniques. Though still new, the use of CS-AFDM in the diagnostic imaging of embankment dams has been tested with sufficient frequency and in a sufficiently diverse set of circumstances to begin drawing some general conclusions about its overall utility. This paper will detail the latest developments in the evolution of this technology, focusing in particular on its recent use at Wolf Creek.

The properties of this CS-AFDM procedure make it especially effective in karst environments, such as those underlying the Wolf Creek Dam. Because the CS-AFDM procedure relies on the broad diffusion of electricity rather than the sinking of targeted boreholes to perform flow path surveys, it is much better equipped to capture the elusive features of karst terrains. Its recent deployment at the Wolf Creek Dam provides an excellent opportunity to analyze its capacities in this type of geology.

[190] President and Professional Engineer, Willowstick Technologies, LLC., 11814 S. Election Rd., Ste. 100, Draper, UT 84020, vkofoed@willowstick.com
[191] VP Business Development, MBA, Willowstick Technologies, LLC., 11814 S. Election Rd., Ste. 100 Draper, UT 84020, prollins@willowstick.com

NOTES

SEEPAGE AND PIPING TOOLBOX — OVERVIEW

John Cyganiewicz [192]
George Sills[193]
Robin Fell[194]
Richard Davidson[195]
Mark Foster[196]
Noah Vroman[197]

ABSTRACT

One of the leading causes of failure of both new and old embankment dams is by internal erosion or piping. To analyze the problem by risk methods necessitates the development of methodology to guide the estimation of failure probabilities. However, the risk of piping is one of the most complex and difficult mechanisms to characterize and has generally required subjective judgments best made by a very limited number of experienced dam engineers. Research at the UNSW has attempted to bring experienced based judgments into the process, but far more guidance is needed for the less experienced risk estimator. Since about 1998, efforts in both Australia and the United States have been occurring collaboratively to develop such a methodology. Starting in 2005, the Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (USACE) embarked on an alliance to complete a 'joint' document that both agencies could use when analyzing the risk of their inventory of dams for internal erosion and piping failure modes. Both agencies financially sponsored a contract with URS Corporation, who included expertise from within the Australian dams' community, to prepare the toolbox. The toolbox has been incorporated into a comprehensive spreadsheet which has been trialed by the three organizations on one USACE and one Reclamation dam. This paper discusses the development of the methodology and an overview of this landmark process.

[192] Technical Service Center, Bureau of Reclamation, PO Box 25007, Attn: 86-68311, Denver, CO 80225, jcyganiewicz@do.usbr.gov

[193] Geotechnical and Earthquake Engineering Branch, USACE Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, georgesills@bellsouth.net.

[194] School of Civil and Environmental Engineering, University of New South Wales, Sydney 2052 Australia, r.fell@unsw.edu.au

[195] URS Corporation, 8181 East Tufts Ave., Denver, CO 80237, Richard_Davidson@URSCorp.com

[196] URS Australia Pty Ltd. Level 3, 116 Miller St, North Sydney, 2060 Australia, Mark_Foster@URSCorp.com

[197] Geotechnical and Earthquake Engineering Branch, USACE Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, Noah Vroman@erdc.usace.army.mil

NOTES

SEEPAGE AND PIPING TOOLBOX — INITIATION OF INTERNAL EROSION

Robin Fell[198]
Mark Foster[199]
Richard Davidson[200]
John Cyganiewicz[201]
George Sills[202]
Noah Vroman[203]

ABSTRACT

There are many performance mechanisms with embankment dams which can initiate internal erosion and piping. The fundamental challenge of the seepage and piping toolbox is to provide comprehensive guidance on the likelihood of these various mechanisms given specific known, observed, or postulated conditions. Mechanisms considered include cracking due to abutment and longitudinal alignment geometry, differential settlement, desiccation, earthquakes, defects along conduits and penetrations, cracking along spillway walls, hydraulic fracturing in low stress zones, poorly compacted zones within the embankment core, backward erosion and suffusion in cohesionless soils in the foundation, and many other potential flow paths. Included in the consideration of initiation is the erodibility of the embankment fill and foundation material. Methods have been recently developed to assess erodibility once a defect exists using the hole erosion tests. The toolbox allows the evaluator to group failure mechanisms to the operable conditions and provides guidance on assessing probabilities based on experience, case histories, material types, lab testing, and computational analysis. Guidance is provided in the form of tables and probabilities. The first important step of initiation usually drives the remainder of the seepage and piping failure event tree.

[198]School of Civil and Environmental Engineering, University of New South Wales, Sydney 2052 Australia, r.fell@unsw.edu.au.
[199]URS Australia Pty Ltd. Level 3, 116 Miller St, North Sydney, 2060 Australia. Mark_Foster@URSCorp.com.
[200]URS Corporation, 8181 East Tufts Ave., Denver, CO 80237. Richard_Davidson@URSCorp.com.
[201]Technical Service Center, Bureau of Reclamation, PO Box 25007, Denver, CO 80225, jcyganiewicz@do.usbr.gov
[202]Geotechnical and Earthquake Engineering Branch, USACE Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199. georgesills@bellsouth.net
[203]Geotechnical and Earthquake Engineering Branch, USACE Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199. Noah.D.Vroman@erdc.usace.army.mil@usace.army.mil.

NOTES

SEEPAGE AND PIPING TOOLBOX – CONTINUATION, PROGRESSION, INTERVENTION AND BREACH

Mark Foster[204]
Robin Fell[205]
Noah Vroman[206]
John Cyganiewicz[207]
George Sills[208]
Richard Davidson[209]

ABSTRACT

This paper describes the assessment of the continuation, progression, detection and breach phases of the internal erosion process. After internal erosion has initiated, the next step is continuation which looks at the filter compatibility of the various materials which comprise the dam section or foundation. The latest research on the extent of erosion through porous media is included in methods for evaluation of gradational limits. The potential adverse effects of segregation and internal instability of filters or other zones are also considered in the assessment of continuation. If piping can continue, then the probability of progression is next assessed by looking at the ability of the piping soil to hold a roof and the ability of upstream materials to fill cracks or limit flows through the embankment. The detection and intervention phase considers whether the development of internal erosion is likely to be detected, and if so, the likelihood of intervening actions stopping the process. The assessment considers the ability to observe leakage and to intervene within the time that the failure path develops. Breach can occur by gross enlargement of the pipe, slope instability, unravelling of the embankment or sinkhole development. These remaining branches in the seepage and piping failure event tree provide the numerical estimate of probability of failure.

[204] URS Australia Pty Ltd. Level 3, 116 Miller St, North Sydney, 2060 Australia. mark_foster@urscorp.com.
[205] School of Civil and Environmental Engineering, University of New South Wales, Sydney 2052 Australia, r.fell@unsw.edu.au.
[206] Geotechnical and Earthquake Engineering Branch, USACE Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, Noah.D.Vroman@erdc.usace.army.mil.
[207] Technical Service Center, Bureau of Reclamation, PO Box 25007, Denver, CO 80225, jcyganiewicz@do.usbr.gov.
[208] Geotechnical and Earthquake Engineering Branch, USACE Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199. georgesills@bellsouth.net
[209] URS Corporation, 8181 East Tufts Ave., Denver, CO 80237. richard_davidson@urscorp.com.

NOTES

SEEPAGE AND PIPING TOOLBOX — BETA TRIAL CASE HISTORIES

Noah Vroman[210]
John Cyganiewicz[211]
George Sills[212]
Robin Fell[213]
Richard Davidson[214]
Mark Foster[215]

ABSTRACT

A comprehensive Alpha and Beta trial of the seepage and piping toolbox was conducted to provide a true test of the accuracy, reliability and reproducibility of the methodology. During the Alpha trial, two representative dams were evaluated using the toolbox by representatives of the Bureau of Reclamation (Reclamation), US Army Corps of Engineers (USACE) and URS who were not involved in the development of the methodology. The first dam was Arkabutla, located in Mississippi and owned by the USACE. Arkabutla is a homogenous earth fill embankment constructed in 1943. Arkabutla has a structural height of 65ft, a crest length of 10,700 ft, and is founded on an alluvial foundation. The second dam selected for the trial was Soldier Creek, located in Utah and owned by Reclamation. Soldier Creek is a zoned embankment finished shortly after the Teton Dam failure. The dam has a structural height of 272 ft.; a volume of over 3.2 million yards; and a crest length of 1,290 ft. The Alpha trials provided valuable input to make the toolbox easier to navigate, more user friendly, and capable of producing consistent interpretations of probability. The three sets of probability estimates came within 1 order of magnitude of each other. From this trial, a Beta version of the toolbox was prepared and was used for further trials. These trials consisted of each agency performing risk analyses on various dams within their inventory. The trails were performed by engineers not familiar with past development of the toolbox and therefore brought 'fresh eyes'. After this trial, two further workshops were conducted to iron out final changes and prepare the final version of the toolbox.

[193]Geotechnical and Earthquake Engineering Branch, USACE Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, Noah.D.Vroman@erdc.usace.army.mil
[211]Technical Service Center, Bureau of Reclamation, PO Box 25007, Denver, CO 80225, jcyganiewicz@do.usbr.gov
[212]Geotechnical and Earthquake Engineering Branch, USACE Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, georgesills@bellsouth.net
[213]School of Civil and Environmental Engineering, University of New South Wales, Sydney 2052 Australia, r.fell@unsw.edu.au
[214]URS Corporation, 8181 East Tufts Ave., Denver, CO 80237, Richard_Davidson@URSCorp.com
[215]URS Australia Pty Ltd. Level 3, 116 Miller St, North Sydney, 2060 Australia, Mark_Foster@URSCorp.com

NOTES

WATER STORAGE — AN ENVIRONMENTAL NECESSITY?

Blaine N. Dwyer, P.E., D.WRE[216]

ABSTRACT

Multipurpose water storage has been a necessity in the economic development of river basins in the United States and around the world. Today, some of the most challenging aspects of dam and reservoir management center on regulatory approval processes and how specific releases can be made to enhance environmental conditions at critical times. In two adjacent river basins in the western U.S., serious consideration is being given to construction of new dams as part of federally-sponsored endangered species recovery programs. Well-timed reservoir releases can more precisely control downstream flows to meet the very specific needs of the species and the riverine and riparian habitats upon which they depend. This paper summarizes the flow requirements leading to the on-going water storage considerations and then contrasts these two U.S. proposals with conditions in two other geographically, hydrologically, and politically diverse foreign river basins to compare and contrast the degree to which water storage may become an environmental necessity. Current conditions in the basins are reviewed in the context of historic water storage and environmental policies followed by summaries of the major water storage projects. Reallocation of existing storage and/or the construction of new storage to meet future environmental needs and to sustain other current and potential human uses of the limited water supplies may be required in each basin.

[216] Vice President – Water Resources, Boyle Engineering Corporation, 215 Union Blvd., Suite 500, Lakewood, CO 80228, bdwyer@boyleengineering.com

NOTES

RE-OPERATION OF MULTI-PURPOSE RESERVOIRS FOR ECONOMIC AND ENVIRONMENTAL BENEFITS

Felix Froehlich[217]
Robert Dittmann[218]
Dirk Muschalla[219]
Manfred Ostrowski[220]
Reinhard Pohl[221]

ABSTRACT

This paper is a result of an ongoing research project focusing on the reduction of flood risk along rivers regarding both the failure probability of affected structures as well as the damage inflicted upon socio-economic values downstream of reservoirs. At the same time, reservoir releases are modified such that dam-induced hydrologic alteration downstream is reduced, thus improving downstream habitat conditions. This is achieved by developing tools that allow for improved, model-based reservoir regulation with dynamic releases, producing both economic as well as environmental benefits.

A reservoir operation model is used to define dynamic releases which are then optimized with regard to multiple, partly conflicting, objectives (flood protection, dam safety, hydropower production, water supply, hydrologic alteration) using evolutionary algorithms. The methodology is applied to case studies of existing multi-purpose reservoirs in Germany and improves existing reservoir operating rules regarding both economic as well as environmental aspects. Compared to conventional operating rules, the dynamic operating rule keeps the reservoir storage levels at a more constant level and produces a more variable reservoir release pattern that follows the natural flow regime. As a result, hydrologic alteration can be reduced significantly, while the storage levels better adhere to the reservoir's flood guide.

[217] Research Associate, Section of Engineering Hydrology and Water Management, Institute of Hydraulic and Water Resources Engineering, Technische Universität Darmstadt, Petersenstrasse 13, D-64287 Darmstadt, Germany, froehlich@ihwb.tu-darmstadt.de

[218] Research Associate, Institute of Hydraulic Engineering, Faculty of Civil Engineering, Technical University of Dresden, D-01062 Dresden, Germany, robert.dittmann@tu-dresden.de

[219] Lecturer, Section of Engineering Hydrology and Water Management, Institute of Hydraulic and Water Resources Engineering, Technische Universität Darmstadt, Petersenstrasse 13, D-64287 Darmstadt, Germany, muschalla@ihwb.tu-darmstadt.de

[220] Professor, Section of Engineering Hydrology and Water Management, Institute of Hydraulic and Water Resources Engineering, Technische Universität Darmstadt, Petersenstrasse 13, D-64287 Darmstadt, Germany, ostrowski@ihwb.tu-darmstadt.de

[221] Professor, Institute of Hydraulic Engineering, Faculty of Civil Engineering, Technical University of Dresden, D-01062 Dresden, Germany, reinhard.pohl@tu-dresden.de

NOTES

WATER RESOURCES CAPITAL IMPROVEMENTS IN A POST-CONFLICT ENVIRONMENT: THE IRAQ EXPERIENCE

Azad Mohammadi, PhD, PE, PMP[222]
Hassan Janabi, PhD[223]

ABSTRACT

Although much of the US-funded reconstruction of Iraq infrastructure targeted the restoration and rehabilitation of post-conflicts utility infrastructure, attempts to plan for and implement water capital improvement projects have continuously been hindered by combinations of: centrally planned water management practices; politically driven vast irrigation and drainage schemes carried out by the previous regime in southern Iraq; unilateral massive water development projects in the upper riparian states to Tigris and Euphrates rivers; and inefficient policies and procedures for procurement, project management systems, and standardization of contracting procedures. Additionally, Iraq's ponderous bureaucracy and deferred maintenance continue to pose major challenges, not only to sustaining and maintaining existing water super structures, but also to effective planning for the required investments in the water sector. Nine large dams, eighteen major barrages and 275 pump stations regulate the flow in Tigris and Euphrates rivers. As part of a broader effort to develop the Governments of Iraq's administrative capacity and strengthening the management of executive government institutions such as Ministry of Water Resources, the USAID has, since August 2006, launched a National Capacity Development (NCD) project, also known by its Arabic name, TATWEER to provide hands-on technical assistance to Iraq's ministries to improve public management through extensive focused training on: fiscal management; strategic planning and policy development; information technology; project management; personnel management and administration; and leadership and communications.

[222] President, Azad Engineering, Inc., Beaverton, Oregon, USA, info@aeincpdx.com.
[223] Senior Advisor & Ministry Liaison Lead, Stanley Baker Hill, LLC, Baghdad, Iraq, hassan.janabi@pco-iraq.net

NOTES

MARMOT DAM REMOVAL

J.W. Sager[224]
M. R. Meyer[225]
T. Keller[226]

ABSTRACT

Marmot Dam was the upstream diversion dam for Portland General Electric Company's Bull Run Hydropower Project Decommissioning. This paper will present the design and construction for the removal of Marmot Dam located at RM 30 on the Sandy River in northwestern Oregon. The dam was a 57-foot high roller compacted concrete (RCC) structure with a spillway crest length of 345 feet. The current dam was constructed in 1989 at the site of a much older timber crib dam that was originally constructed in 1913. PGE completely removed the RCC dam to the level of the original river bed, including a section of the original timber crib dam just upstream, the canal inlet and headworks, and the fish ladder within one construction season, from July 1 to October 15, 2007. This work was accomplished during an extended in-water work period approved by the Oregon Department of Fish and Wildlife (ODFW). An upstream cofferdam was designed to withstand flows up to a three-year return flood. Dewatering wells were installed to maintain stability and allow removal of the concrete structures in the dry. Controlled blasting and excavators were used to remove the RCC concrete and remaining timber crib dam section, and fish ladder. A controlled failure of the cofferdam and initial release of the retained sediments was allowed to occur on October 19, 2007 during a fall storm event. This selected alternative for removal in a single season will eventually deliver approximately 960,000 cubic yards of sediment downstream.

[224] Cornforth Consultants, Inc., 10250 S.W. Greenburg Road, Suite 111, Portland, OR 97223, jsager@cornforthconsultants.com
[225] Cornforth Consultants, Inc., 10250 S.W. Greenburg Road, Suite 111, Portland, OR 97223, mmeyer@cornforthconsultants.com
[226] Portland General Electric Company, 121 S.W. Salmon Street, Portland, OR 97204, tim.keller@pgn.com

NOTES

REMOVAL OF SAVAGE RAPIDS DIVERSION DAM — PART ONE

Richard D. Benik[227]

ABSTRACT

Savage Rapids Diversion Dam is a combination concrete gravity and multiple-arch diversion facility located on the Rogue River, in southwestern Oregon. The facility consists of a pumping plant, canals, an overflow dam, and fish ladders. Originally constructed in 1921-22 by private developers, the facility has been diverting flows for irrigation to both sides of the river ever since. Species of anadromous fish are present in the Rogue River year round, sometimes in very large numbers. Despite having a fish ladder on each abutment, the dam is considered to be a major impediment to fish migration. The recommended least-cost alternative to improve fish passage and maintain irrigation diversions is to construct a new diversion facility and remove a portion of the existing dam. The removal of the dam will restore fish passage and river navigation to natural conditions. Dam removal is currently scheduled for 2009.

[227] Civil Engineer, Bureau of Reclamation, PO Box 25007, Denver, Colorado 80225, rbenik@do.usbr.gov

NOTES

A CHILOQUIN ROMANCE — RESTORING THE SPRAGUE RIVER

Thomas E. Hepler, P.E.[228]

ABSTRACT

Chiloquin Diversion Dam is a concrete gravity structure constructed by the U.S. Indian Service (USIS) in 1914, and is located on the Sprague River in south central Oregon. Despite the existence of three fish ladders, the dam effectively blocks 95 percent of the potential spawning range of the Federal endangered Shortnose sucker and Lost River sucker within the Sprague River watershed. Federal legislation passed in 2002 required a study of the feasibility of providing adequate upstream and downstream passage for sucker fish at Chiloquin Dam, including an alternate method of water delivery to the Modoc Point Irrigation District (MPID), which currently owns and operates the dam.

Removal of Chiloquin Dam, including the construction of a small pumping plant on the Williamson River to maintain water deliveries to the MPID Main Canal, was selected as the consensus alternative through a collaborative process between the Bureau of Reclamation (Reclamation), Bureau of Indian Affairs (BIA), MPID, Oregon Department of Fish and Wildlife (ODFW), Klamath Indian Tribes, and others. Final designs and specifications were prepared by Reclamation, and a construction contract for removal of Chiloquin Dam was awarded in February 2007, for completion by December 2008. This paper documents the existing conditions, decision-making process, designs, and construction for this fish passage project.

[228] Civil Engineer, Bureau of Reclamation, P.O. Box 25007, Denver, Colorado 80225, thepler@do.usbr.gov

NOTES

EVALUATING DRAINS IN A RISK-BASED CONTEXT

Bill Fiedler[229]
Lloyd Crutchfield[230]
Gregg Scott[231]

ABSTRACT*

In 2004, the Bureau of Reclamation published a manual on drains for dams and associated structures. The manual provides a comprehensive background on the design, analysis, evaluation and maintenance of drainage systems for dams. Case histories are presented in the manual that cover a full range of drainage systems in which cleaning exercises were performed. The manual reinforces the importance of drainage systems for dams and their role in ensuring dam stability. Maintaining drains, however, is costly and competes for limited O&M budgets with other recommended maintenance activities. This paper summarizes key information in Reclamation's Drain Manual and describes how risk analysis can be used to evaluate the need for and the benefits of maintaining a drainage system. Risk analysis case histories are used to illustrate how varying degrees of drain effectiveness have been considered in failure mode event trees.

[229] Civil Engineer, Waterways and Concrete Dams, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, 303-445-3248, bfiedler@do.usbr.gov
[230] Supervisory Geologist, Engineering Geology, Bureau of Reclamation, PO Box 25007, 86-68120, Denver, CO 80225, 303-445-3074, lcrutchfield@do.usbr.gov
[231] Geotechnical Engineer, Geotechnical Engineering Group 2, Bureau of Reclamation, PO Box 25007, 86-68312, Denver, CO 80225, 303-445-3233, gscott@do.usbr.gov
*This paper is not included in the Conference Proceedings CD.

NOTES

LABORATORY STUDIES OF HIGH VELOCITY FLOWS OVER OPEN OFFSET JOINTS

K. Warren Frizell[232]

ABSTRACT

Laboratory tests were completed in Reclamation's Water Resources Research Laboratory to extend the available data on uplift pressures generated by high velocity flows over offset joints. In addition, magnitudes of flows into the joints or cracks were measured for various configurations. Three joint geometries were tested: sharp edges (90-degree), 1/8-inch chamfered edges (45-degree), and edges with a 1/8-inch-radius in combinations of joint/crack gaps ranging from 1/8-inch to 1/2-inch and offsets into the flow ranging from 1/8-inch to 3/4-inch. Only sharp-edged joints will be reported in this paper. Velocities ranging from about 10 ft/s up to 55 ft/s were tested. Mean uplift pressures downstream from the offset were measured for all cases. The cavity beneath the test section could be closed, generating the maximum uplift, or opened to allow flow to enter the cavity through the joint/crack. This test facility feature allowed for measurement of a slightly reduced uplift pressure and flow rates through the open joint/crack area. Uplift pressure and flow rate data from this study will be used to reduce the uncertainty in analyses used during risk assessments to provide improved estimates of the level of effort required to bring a spillway or outlet works into a safe operating condition for a variety of geometries.

[232] Research Hydraulic Engineer, Technical Service Center, Bureau of Reclamation, Denver, CO 80225, wfrizell@do.usbr.gov

NOTES

STRUCTURAL EVALUATION AND REHABILITATION OF MONTGOMERY DAM LIFT GATES

William A. Karaffa, P.E.[233]
Paul A. Surace, P.E.[234]

ABSTRACT

Placed in operation in 1936, the Montgomery Locks and Dam is one of the oldest navigation structures on the upper Ohio River. This 70-year old gated dam maintains an 18 mile long shallow-draft pool on the Upper Ohio River, making access possible to the Port of Pittsburgh, the second busiest inland port in the nation. Shipping through the Port of Pittsburgh each year, equates to an annual benefit to the region of more than $873 million.

In the spring of 2006, the Pittsburgh District Corps of Engineers, while performing an overall condition inspection of the dam, found four of the ten vertical lift gates to be exhibiting extreme deterioration. The severity of this deterioration prompted the District to implement an accelerated structural investigation of the gates. This investigation was to determine the life expectancy and potential failure modes of the gates. To successfully complete this mission a complex structural analytical computer model was created that incorporated the results of a detailed on-site structural inspection of all gate members and connections, force flow patterns determined by a strain gage evaluations and material properties through coupon testing. These efforts resulted in a finding that all ten dam gates were subject to immediate failure from a barge impact or an extreme ice condition, with four of the dam gates being on the brink of a catastrophic failure while under normal operating pool conditions. Operational restrictions were immediately placed on the most deteriorated dam gates while an effort to design emergency repairs was implemented. The exigent nature of the dam gate situation was further exacerbated on October 18, 2006, when three breakaway barges impacted and destroyed two of the least deteriorated dam gates. This paper presents in detail, the inspection techniques and analytical methods used to evaluate the deteriorated condition of the Montgomery dam gates.

[233] Civil Engineer, U.S. Army Corps of Engineers, Pittsburgh District, 1000 Liberty Avenue, Pittsburgh, PA 15222, email: William.Karaffa@usace.army.mil
[234] Structural Engineer, U.S. Army Corps of engineers, Pittsburgh District, 1000 Liberty Avenue, Pittsburgh, PA 15222, email: Paul.A.Surace@usace.army.mil

NOTES

GIS-BASED SOIL EROSION MODELING WITH CLIMAGE CHANGE SCENARIO IN IMHA DAM BASIN, KOREA

Geun-Sang Lee[235]
Kyung-taek Yum[236]
Deuk-koo Koh[237]

ABSTRACT

The object of the present study is to estimate the potential effects of climate change and land use on soil erosion in the mid-east Korea. Simulated precipitation by CCCma climate model during 2030-2050 is used to model predicted soil erosion, and results are compared to observation. Simulation results allow relative comparison of the impact of climate change on soil erosion between current and predicted future condition. Expected land use changes driven by socio-economic change and plant growth driven by the increase of temperature and CO_2 are taken into accounts in a comprehensive way. Mean precipitation increases by 17.7% (24.5%) for A2 (B2) during 2030-2050 compared to the observation period (1966-1998). In general predicted soil erosion for the B2 scenario is larger than that for the A2 scenario. Predicted soil erosion increases by 48%~90% under climate change except the scenario 1 and 2. Predicted soil erosion under the influence of temperature-induced fast plant growth, higher evapotranspiration rate, and CO_2 fertilization effect (scenario 5 and 6) is approximately 25% less than that in the scenario 3 and 4. On the basis of the results it is said that precipitation and the corresponding soil erosion is likely to increase in the future and care needs to be taken in the study area.

[235] Principal Researcher, Korea Institute of Water and Environment, K-water, Daejeon, ilovegod@kwater.or.kr
[236] Director, Dam and Watershed Department, K-water, Daejeon, yumkt@kwater.or.kr
[237] Research Fellow, Korea Institute of Water and Environment, K-water, Daejeon, dkkoh@kwater.or.kr

NOTES

ENHANCEMENT PROGRAM FOR HYDROLOGIC SAFETY OF EXISTING DAMS IN KOREA

Hyun Lee[238]
Deukkoo Koh[239]
Kyungtaek Yum[240]

ABSTRACT

Due to the climate change, recent hydrologic records tend to exceed the design storms for the dams in Korea, most of which were estimated several decades ago. In order to enhance the hydrologic dam safety, the design standard for dams was reinforced from the frequency flood to PMF (Probable Maximum Flood) after a series of large scale typhoons in 2002 and 2003. With the new design standards, hydrologic safety of existing dams has also been re-evaluated. From the results of re-evaluation, Korean government and K-water established a large scale dam reinforce program against the extreme hydrologic conditions for the existing multipurpose dams. In this paper, the methods and results of re-evaluation of hydrologic safety of existing dams are described along with the current activities on several dams.

[238] Engineer, Water Resources Management Department, K-water, Daejeon, 2hyuny@kwater.or.kr
[239] Head Researcher, Korea Institute of Water and Environment, K-water, Daejeon, dkkoh@kwater.or.kr
[240] Director, Water Resources Management Department, K-water, Daejeon, yumkt@kwater.or.kr

NOTES

EVALUATION OF PROPOSED CAMPUS CONSTRUCTION ON EXISTING LEVEE — NEW TCCD DOWNTOWN CAMPUS, FORT WORTH, TEXAS

Marc T. Miller, P.E.[241]
Elena Sossenkina[242]
Jie Yu, P.E.[243]
Mike Shiflett , P.E.[244]

ABSTRACT*

Tarrant County College District (TCCD) is one of the fastest growing community colleges in Texas. The TCCD plans to build a new campus in downtown Fort Worth bisected by the Trinity River. The two main campus buildings will be positioned on opposite sides of the river and linked by a sky bridge. The proposed construction on the right side of the river will require excavation at the landside (downstream) toe of an existing levee and penetration into the levee for bridge supports. Since this levee is under the jurisdiction of the Fort Worth District of the United States Army Corps of Engineers (Corps), the Corps approval is required before construction in the area could proceed. The Corps would only approve the project under the condition that engineers could demonstrate that the safety of the levee and its performance would not be jeopardized by the proposed construction.

A study was conducted to evaluate the impact of the proposed campus construction on the levee performance. As part of this study, a risk analysis has been completed comparing the existing conditions to post-construction conditions, based on seepage and slope stability evaluations. The results of the seepage analyses indicated that additional seepage control measures are required to maintain stability of the levee. The primary recommendation resulting from this analysis called for construction of a 400-foot-long diaphragm wall in the immediate vicinity of the campus building. The proposed diaphragm wall will serve primarily as a seepage cut-off, but will also be designed as a flood control wall. In the event of a levee failure within the protected reach, the flood will be controlled by the diaphragm wall. This paper will provide an overview of the site investigation, summarize the details of the seepage and stability analyses performed for this project, and discuss the risk-based rationale for recommendations and conclusions.

[241] Project Manager and Lead Engineer, Kleinfelder, Fort Worth, TX, mtmiller@kleinfelder.com phone: (817)429-6692
[242] Geotechnical Engineer, Kleinfelder, Golden, CO, esossenkina@kleinfelder.com phone: (303) 237-6601
[243] Geotechnical Engineer, Kleinfelder, Golden, CO, jyu@kleinfelder.com phone: (303) 237-6601
[244] Principal Geotechnical Engineer, Kleinfelder, Fort Worth, TX, mmshiflett@kleinfelder.com phone: (817)429-6692
*This paper is not included in the Conference Proceedings CD.

NOTES

DEEP GROUT CURTAIN CUTOFF FOR LARGE STORAGE RESERVOIRS IN ROCK

Faruk Oksuz[245]
Cary Hirner[246]

ABSTRACT

The nation's most impressive combined sewer overflow tunnels and reservoirs system is now in its final stretch of construction in Chicago. The Metropolitan Water Reclamation District of Greater Chicago's (District) award-winning Tunnel and Reservoir Plan (TARP) continues to set the precedence on how to improve water quality of urban streams and manage overflows of the sanitary systems during significant rain events. The three big reservoirs, O'Hare, McCook, and Thornton Composite Reservoirs, will store the combined sewer overflows (CSOs) and flood waters when the treatment plant and deep tunnel storage capacities are exceeded and until treatment capacity become available. Once completed in 2014, the McCook Reservoir will provide approximately 10 billion gallons storage capacity for CSOs prior to treatment at the Stickney Wastewater Treatment Plant.

The McCook Reservoir design includes tunnels, shafts, chambers, buildings, gates and valves. It also features an overburden cut-off wall and a nearly 400-ft double-row deep grout curtain around the reservoir perimeter to control groundwater infiltration and CSO exfiltration. The purpose of the overburden cut-off wall is to reduce the seepage of groundwater through the overburden to minimize groundwater infiltration and to prevent overburden slope failure in the reservoir walls due to excessive flow. The purpose of the grout curtain is to minimize the infiltration and exfiltration from the reservoir. Excessive infiltration of groundwater would result in increased pumping and water treatment costs. Exfiltration of CSOs is an environmental concern that may result in groundwater contamination in the bedrock aquifer. Similar grout curtain design is also considered for the Thornton Composite reservoir that is also being constructed in rock with depths nearing to 500-ft below grade.

Black & Veatch has completed the design and construction of the initial test grout curtain for McCook and is currently in the process of designing a similar grout curtain for the Thornton reservoir. This paper will present the design and lessons-learned for design and installation of grout curtains for both facilities. The state-of-the-art grouting project included technology, material comparisons, and supplementary findings that are beneficial to the entire industry in improving the quality and effectiveness of deep grout curtains for dams and reservoirs.

[245] Practice Leader for Dams, Levees, and Reservoirs, Black & Veatch Corporation, 101 N. Wacker Drive, Chicago, IL 60606, oksuzf@bv.com
[246] Project Manager, Black & Veatch Corporation, Kansas City, MO, 64114, hirnercr@bv.com

NOTES

EVALUATION OF RISK FOR A NEW DESIGN AT THE CONCEPTUAL LEVEL

Phoebe Percell[247]
Rick Poeppelman[248]
Bill Fiedler[249]
Ernie Hall[250]

ABSTRACT*

Reclamation recently performed a risk analysis on the preliminary designs for the Joint Federal Project auxiliary spillway (JFP). The JFP is being jointly designed and funded by Reclamation and the U.S. Army Corps of Engineers (USACE). The JFP will be a gated concrete lined spillway designed to provide at least 200-year flood protection for downstream populations and safely pass the current probable maximum flood for Folsom Dam. During this risk analysis, risk based methodology was applied to the proposed designs to help determine critical design features and appropriate design loads. Potential failure modes were identified and evaluated for static, hydrologic and seismic loadings. For each potential failure mode considered to have a reasonable (plausible) likelihood of occurring, an estimated population at risk and potential loss of life was developed. The failure modes were decomposed in event trees. The risk analysis methodology helped Reclamation and the USACE determine appropriate seismic design loadings that if used to design the structure, would satisfy Reclamation's Public Protection Guidelines (risk guidelines) after construction is completed. As the risk analysis was performed, it became obvious which design features were most critical for each potential failure mode. With these critical design features identified, special attention can be paid during final design of these features to ensure risk guidelines will be met.

[247] Civil Engineer, Waterways and Concrete Dams, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, 303-445-3253, ppercell@do.usbr.gov
[248] Chief, Design Branch, American River Division, Sacramento District, U.S. Army Corps of Engineers, 1325 J Street, Rm 1154, Sacramento, CA, 916-557-7301, Rick.L.Poeppelman@usace.army.mil
[249] Civil Engineer, Waterways and Concrete Dams, Bureau of Reclamation, PO Box 25007, 86-68130, Denver, CO 80225, 303-445-3248, bfiedler@do.usbr.gov
[250] Civil Engineer, Waterways and Concrete Dams, Bureau of Reclamation
PO Box 25007, 86-68130, Denver, CO 80225, 303-445-3244, ehall@do.usbr.gov
*This paper is not included in the Conference Proceedings CD.

NOTES

INVESTIGATION AND EVALUATION ON THE SAFETY OF SOYANGGANG-DAM AUXILIARY SPILLWAY TUNNEL ALONG LARGE FAULT ZONES

Young-Kwon You[251]
Yang-Soo Yoo[252]
Kyung-Taek Yum[253]
Moo-Young Song[254]
Sung-Hun Kwak[255]
Young-Wan Shin[256]

ABSTRACT

The Soyanggang Multipurpose Dam, completed in 1973, is the biggest central core type rockfill dam in Korea with the gross storage capacity of $2{,}900\times10^6\,m^3$, flood control capacity of $500\times10^6\,m^3$, and flood water level of EL. 198.0m. The initial spillway design was for a 200-year event having an inflow of 10,500 m^3/sec. The project has experienced rainfall events that exceeded the original spillway design inflow in 1984 and 1990. In response to these events and based on the Enhancement Program for Hydrologic Safety of Existing Dams, a review on the flood control capacity of the dam was performed. Rehabilitation project of Soyanggang dam with construction of auxiliary spillway parallel tunnel; height of 15-18m, width of 15-24m, has been under construction since 2004. Some faults unexpected in design stages were revealed in the transition section of Tunnel-1 and Tunnel-2 entrance. Roof falls in the entrance sections of T-1 and T-2 were caused by large faults. Additional borings in ground surface and tunnel were executed. The results of additional geological investigation showed that thrust fault zones widely branched, merged and intersected each other in T-1 and T-2. Therefore the stability of the tunnel was not guaranteed. It was concluded that the original support system was deficient and an alternative support system was needed. The alternative methods, such as cut and cover tunnel, double support system and large steel pipe insertion method, were thoroughly investigated. Double support system was selected as the most suitable substitution. Numerical analyses under consideration of the ground condition proved the tunnel to be stable. However, excessive crown settlement in the portal area was measured during excavation based on the 1st modified design. Additional ground investigation to verify distribution of large faults was done. Consequently, thrust fault areas are increased more than those expected previously. Additional double support system, injection rock bolt, injection steel pipe grouting and tie-rod between T-1 and T-2 pillar are redesigned. Divided excavation sequence is converted from 3 stages to 2 stages in order to close the invert as soon as possible.

[251] Assistant Manager, Water Resources Investigation & Planning Dept., K-water, Korea, geowater@kwater.or.kr
[252] Director, Soyanggang Dam Division, K-water, Korea, yooys@kwater.or.kr
[253] Director, Water Resources Management Department, K-water, Korea, yumkt@kwater.or.kr
[254] Prof. Dept. Geology. Chungnam National University, Korea, mysong@cnu.ac.kr
[255] Vice President, Engineering & Construction, Samsung, Korea
[256] Tunnel & Geotech. Div., Hakyong Eng. Co., Korea