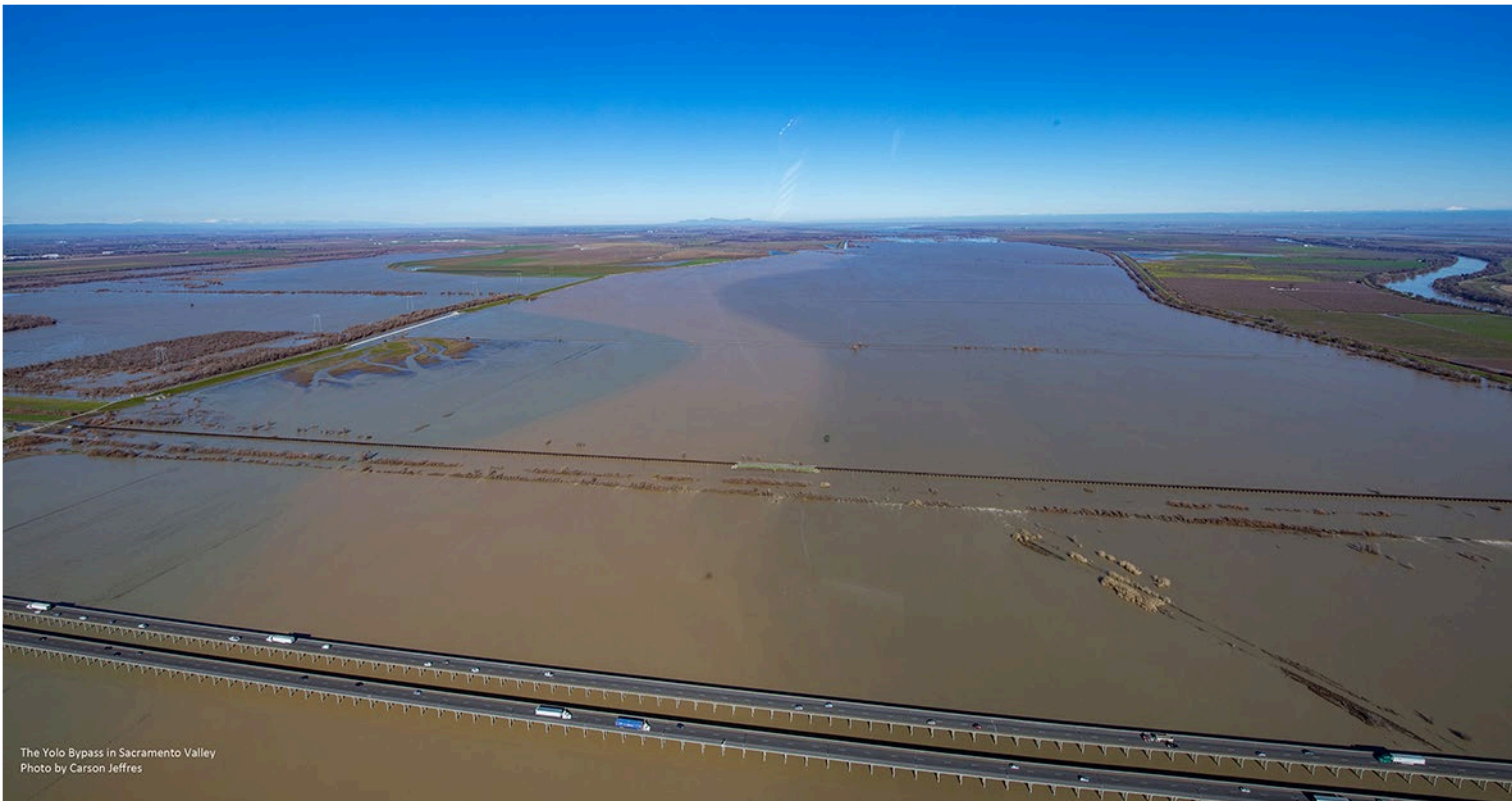


World Environmental and Water Resources Congress 2017



The Yolo Bypass in Sacramento Valley
Photo by Carson Jeffres

International Perspectives, History and Heritage, Emerging Technologies, and Student Papers

Selected Papers from the Proceedings of the
World Environmental and Water Resources Congress 2017
Sacramento, California ■ May 21-25, 2017



EDITED BY
Christopher N. Dunn, P.E., D.WRE



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WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2017

*INTERNATIONAL PERSPECTIVES, HISTORY AND HERITAGE,
EMERGING TECHNOLOGIES, AND STUDENT PAPERS*

SELECTED PAPERS FROM THE WORLD ENVIRONMENTAL AND
WATER RESOURCES CONGRESS 2017

May 21–25, 2017
Sacramento, California

SPONSORED BY
Environmental and Water Resources Institute (EWRI)
of the American Society of Civil Engineers

EDITED BY
Christopher N. Dunn, P.E., D.WRE
Brian Van Weele, P.E., D.WRE



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Preface

We are excited to offer an engaging and challenging array of technical sessions, posters, and accompanying published papers at our Environmental and Water Resources Institute's (EWRI) 17th annual Congress in Sacramento, California. This meeting is a leading venue for professional interaction among engineers and scientists, covering disciplines relating to the needs of critical infrastructure in water and environment. As is pointed out in the American Society of Civil Engineers' Report Card for America's Infrastructure, an investment of over \$3.6 trillion is needed to return the nation's infrastructure to a state of good repair. This Congress contributes in many ways to innovative solutions to this critical problem. We proudly host the meeting under the auspices of the American Society of Civil Engineers (ASCE).

Within the five (5) volumes of the proceedings of the Congress you will find nearly 300 written technical papers from more than 700 oral and poster presentations dealing with the subject areas of the EWRI Councils; a list of subject area tracks is included in the acknowledgements below. Our profession advances through presentations in special state-of-knowledge tracks represented at the Congress. We hope these proceedings serve to enhance your knowledge in these areas and encourage you to follow up with more detailed publications by the same authors, typically found in ASCE technical journals.

World Environmental and Water Resources Congress 2017: International Perspectives, History and Heritage, Emerging Technologies, and Student Papers contains papers organized by the following EWRI Councils:

- **Students Council** whose purpose is to draw students in to the field of civil and environmental engineering through presentations, activities, technical sessions and other activities at EWRI conferences.
- **Standards Council** whose purpose is to coordinate all activities of EWRI related to the establishment, use or discontinuance of standards or other regulatory tools in the area of water and the environment.
- **History and Heritage Committee** whose purpose is collecting, organizing, and disseminating information related to the history and heritage of water resources and environmental engineering.
- **Emerging and Innovative Technologies Committee (Interdisciplinary Council)** whose purpose is to develop and apply emerging and innovative technologies to support the functioning of EWRI, to advance the development, knowledge, and application of emerging and innovative technologies for the planning and management of water resources and the protection and enhancement of the environment; to encourage the reporting, discussion of technical and social issues, and information transfer of applications of emerging and innovative technologies; and to foster the multidisciplinary use of these technologies.
- **International Council** whose purpose is to undertake and facilitate a variety of technical and liaison activities in support of international collaboration and international promotion of the role of the Institute.

Acknowledgments

Preparation and planning for this Congress strongly depends on the dedication of those who plan track subjects, solicit abstracts and papers, oversee reviews of all this material and then “encourage” all authors to provide their material in a timely manner! We are deeply grateful to all who have provided this considerable effort, especially the track chairs listed below:

Track	Chairs
Hydro-Climate/Climate Change Symposium	Dr. M. Levent Kavvas – Volume 3
14th Urban Watersheds Management Symposium	Shirley Clark – Volume 5
Groundwater Symposium	Dr. Amy Chan Hilton – Volume 3
Water Distribution Systems Analysis Symposium	Juan Saldarriaga – Volume 4
Education	Colleen Bronner – Volume 1
Emerging Technologies	David Hill – Volume 1
Environmental	Wendy Cohen, Lisa Hayes – Volume 3
History and Heritage	Lawrence Magura, J. David Rogers – Volume 1
Hydraulics and Waterways	Christina Tsai – Volume 4
International	Ali Mirchi, Dr. Erfan Goharian – Volume 1
Irrigation and Drainage	Thomas W. Ley – Volume 2
Municipal Water Infrastructure Symposium	Ruth Hocker – Volume 5
Planning and Management	Kaveh Madani, Mashor Housh – Volume 2
New Professionals/Professional Development	Cidney Jones – Volume 1
Standards	Dr. Kathlie Jeng-Bulloch – Volume 1
Students	Monica Palomo, Curt Elmore – Volume 1
Sustainability	Joseph Threadcraft – Volume 3
Smart Water Symposium	Sudhir Kshirsagar
Water, Wastewater, and Stormwater	Sri Kamojjala, Bridget Wadzuk – Volume 5
Watersheds	Dr. M. Levent Kavvas, Don Frevert – Volume 2

We also acknowledge the Congress Organizing Committee members, without whose time and efforts the event would not be possible. We also thank others not mentioned here.

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Finally, we acknowledge and thank the staff of the EWRI of ASCE who, in the end, makes it all happen. Most particularly, we thank Gabrielle Dunkley, EWRI's Manager, whose patience, perseverance, good humor, and great organizational talent ensure yet another successful EWRI Congress!

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