

World Environmental and Water Resources Congress 2016

Environmental, Sustainability,
Groundwater, Hydraulic Fracturing, and
Water Distribution Systems Analysis

Selected Papers from the Proceedings
of the 2016 World Environmental
and Water Resources Congress

West Palm Beach, Florida
May 22–26, 2016



Edited by

Chandra S. Pathak, Ph.D., P.E., D.WRE



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WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2016

*ENVIRONMENTAL, SUSTAINABILITY, GROUNDWATER,
HYDRAULIC FRACTURING, AND WATER DISTRIBUTION
SYSTEMS ANALYSIS*

PAPERS FROM SESSIONS OF THE PROCEEDINGS OF THE 2016
WORLD ENVIRONMENTAL AND WATER RESOURCES
CONGRESS

May 22–26, 2016
West Palm Beach, Florida

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Environmental and Water Resources Institute
of the American Society of Civil Engineers

EDITED BY
Chandra S. Pathak, Ph.D., P.E., D.WRE
Debra Reinhart, Ph.D., P.E.



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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) 16th annual Congress in West Palm Beach, Florida. 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) collections of papers in 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 2016: Environmental, Sustainability, Groundwater, Hydraulic Fracturing, and Water Distribution Systems Analysis contains papers organized by the following EWRI Councils, Committees and conference Symposia:

- **Environmental Council** whose purpose is to establish a focal point and provide a forum for civil engineers and scientists to participate and exchange ideas on the full range of innovative and emerging environmental engineering topics.
- **Sustainability Committee (Interdisciplinary Council)** whose purpose is to promote sustainability as a central discipline of EWRI by helping coordinate and optimize sustainability initiatives throughout EWRI, and with external organizations seeking to promote a more sustainable built environment.

- **Symposium: Hydraulic Fracturing (Committee)** whose mission is to develop and disseminate knowledge about hydraulic fracturing through informed technical understanding and to provide solutions to reduce risks to environmental and water resources and mitigate potential impacts.
- **Symposium: Groundwater (Council)** whose purpose is the dissemination of knowledge on many aspects of groundwater including groundwater hydrology, ground water planning and management, and groundwater quality.
- **Symposium: WDSA (Committee):** Water distribution systems analysis (WDSA) involves the quantitative planning, design, operations, management, modeling, and monitoring of hydraulics and water quality of water distribution systems. The purpose of the committee is to provide coordination for all activities within EWRI related to the field of water distribution systems analysis.

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
Symposium Hydro-Climate/Climate Change	Levent Kavvas
13th Urban Watersheds Management Symposium	Shirley Clark
14th Symposium on Groundwater and Hydraulic Fracturing	Antonella Sciortino, Teresa Culver, Amy Chan Hilton
18th Annual Water Distribution Systems Analysis Symposium	Jakobus van Zyl
Education and Research	Cassie Klump
Emerging Technologies	David Hill
Environmental	Marge Bedessem
History and Heritage	J. David Rogers
Hydraulics and Waterways	David Weston, Weiming Wu
International	Kevah Madani
Irrigation and Drainage	Garry Grabow
Planning and Management	Mashor Housh
New Professionals/Professional Development	Jeanne Van Briesen

Standards	Kathlie Jeng-Bulloch
Student	Monica Palomo
Sustainability	Ashlynn Stillwell
Water, Wastewater, and Stormwater	Sri Kamojjala
Watersheds	Levent Kavvas, Don Frevert

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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