THE TEXAS A&M UNIVERSITY SYSTEM

Water Programs

Water Programs

Texas A&M University System

Universities
- Texas A&M University
- Prairie View A&M University
- Tarleton State University
- Texas A&M International University
- Texas A&M University-Corpus Christi
- Texas A&M University-Kingsville
- West Texas A&M University
- Texas A&M University-Commerce
- Texas A&M University-Texarkana
- Texas A&M University-Central Texas
- Texas A&M University-San Antonio

Agencies
- Texas A&M AgriLife Research
- Texas A&M Engineering Experiment Station
- Texas A&M AgriLife Extension Service
- Texas A&M Forest Service
- Texas A&M Engineering Extension Service
- Texas A&M Transportation Institute
- Texas A&M Veterinary Medical Diagnostic Laboratory

Water Programs

Topics

- Texas Water Observatory
- Drought Atlas and Streamflow Simulation
- Water/Energy/Food Nexus Initiative
- Overview of additional water programs and resource material

Water Programs

Texas Water Observatory: Our Capacity &.. Building!

Water Network, Monitoring, Data Portal, Process Understanding, Modeling, Analyses and Assessment

Binayak P. Mohanty
Regents professor and
COALS Chair in Hydrologic Engineering and Sciences
Texas A&M University

Water Programs

Texas Water Observatory

A Four Prong Initiative

- Observatory Network
  - Establishing a series of real-time and near-real time sensor networks in critical zone across Texas monitoring various surface/subsurface water parameters and fluxes (physical, chemical, biological) in various land use land cover, climatic gradient, erosional/depositional environment. It will be supplemented by air-/ space-based remote sensing platforms
- Data Portal
  - web-based access portal, real-time web query, data retrieval, normalization, analysis and interpretation. Water related data would include, but not be limited to temperature, precipitation, humidity, evaporation, groundwater and surface discharge, soil moisture, water demand, water supply, water use, and water quality, among others.
- Modeling
  - The Water Observatory would integrate surface and groundwater hydrology and decision-making modeling; apply, test and refine existing models; develop modeling software and provide technical assistance on problems related to models
- Analyses and Assessment
  - Application of these Water Observatory models for decision makers would provide critical data on climate, surface and groundwater resources, water quality, and threats to water supplies.

Water Programs

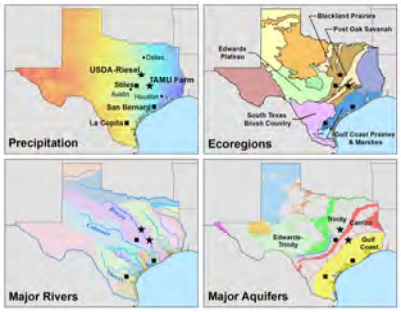
Texas Water Observatory

A Four Prong Initiative

- Interested/Participating Texas A&M Colleges and Departments
  - **College of Agriculture and Life Sciences**
    - Biological and Agricultural Engineering
    - Ecosystems Science and Management
    - Soil and Crop Sciences
    - Wildlife Fisheries Sciences
    - Recreation, Park, and Tourism Sciences
    - Agricultural Economics
  - **College of Geosciences**
    - Geography
    - Geology and Geophysics
    - Atmospheric Sciences
    - Oceanography
    - Water Management and Hydrologic Sciences (Interdisciplinary program)
  - **College of Engineering**
    - Civil Engineering

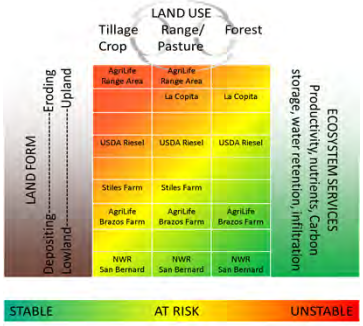
Water Programs

Texas Hydro-Climatology

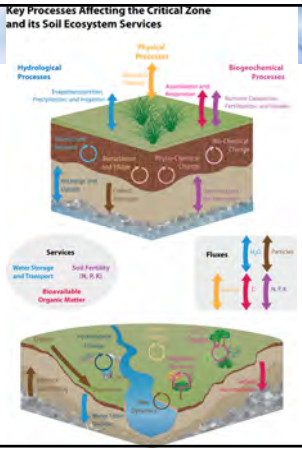


Water Programs

Texas Landscape

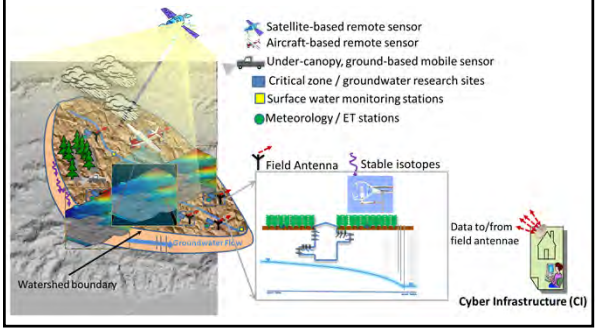


Water Programs



Water Programs

TX Water Observatory Network – A Test Bed Proposal



Water Programs

DROUGHT MODELING AND ATLAS, AND STREAMFLOW SIMULATION

Vijay P. Singh

Water Programs

Drought Definition

1. Meteorological drought is defined as a lack of precipitation over a region for a period of time.

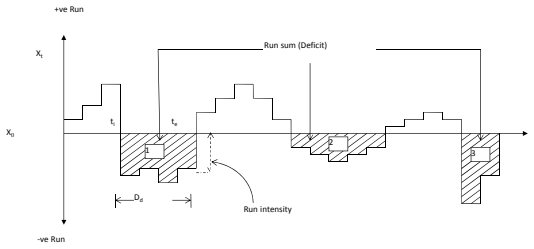
2. Hydrologic drought is related to inadequate surface and subsurface water resources for established water uses of a given water resources management system.

3. **Agricultural drought** refers to declining soil moisture and consequent crop failure.

4. Socio-economic drought is associated with failure of water resources systems to meet water demands, thus associating droughts with supply of and demand for an economic good.

Water Programs

Identification of drought variables



Water Programs

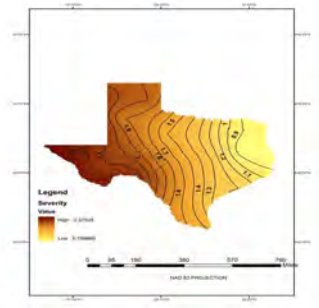
Drought Modeling

Modeling Tools

a. Entropy theory
b. Copula theory
c. Combined entropy-copula theory

Water Programs

Drought Atlas for Texas



Water Programs

Streamflow Simulation

1. Types of Simulation
   a. Single site simulation
   b. Two-site simulation
   c. Multiple site simulation
2. Methods of Simulation and Forecasting
   a. Entropy theory
   b. Copula theory
   c. Combined entropy-copula theory

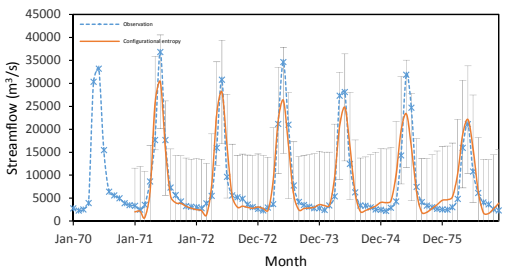
Water Programs

Streamflow Forecasting

1. Types of Forecasting
   a. Univariate forecasting
   b. Multi-variate forecasting
2. Methods of Forecasting
   a. Burg entropy spectral analysis
   b. Configurational entropy spectral analysis
   c. Relative entropy spectral analysis

Water Programs

Upper Colorado River 1971-1976



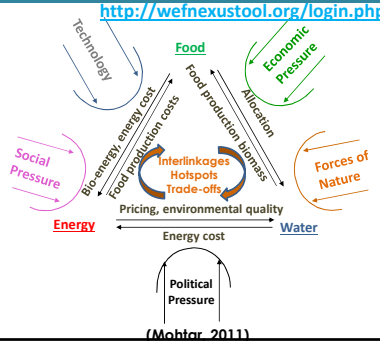
Water-Energy-Food Nexus Approach in Texas

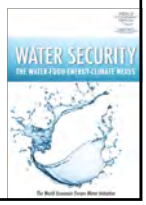
TEXAS A&M UNIVERSITY

Water Programs

Water-Energy-Food Nexus

http://wefnexustool.org/login.php





Water Programs

TAMU Water-Energy-Food Nexus Initiative

1. Create an **integrated** multidisciplinary **platform** to address GRAND CHALLENGES: Water Security, Food Security, Energy Security, etc.
2. Identify and respond to national and global opportunities in **research, education, outreach,** and **policy** implementation from **private** and **public** sources

Water Programs

Water Gap &WEF Nexus in Texas

The 16 regional water planning groups

(Texas State Water Plan 2012)

Case Studies

- Fracking activity scenarios
- Urban Agriculture in San Antonio
- Lubbock: Water Demand-Supply
- Groundwater-Agriculture-Fracking
- Aquifer Recharge in Region J
- Dynamic Water Management

Holistic yet **localized** solutions to bridge the overall water gap

Water Programs

Water-Energy-Transportation Nexus

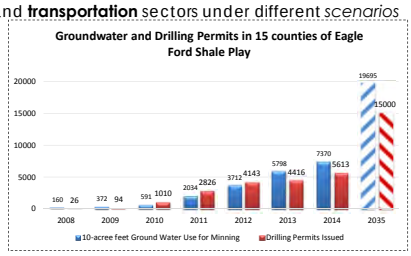
Scope: **Demonstrate** a comprehensive assessment of different scenarios of **Energy Development**, specifically, the impacts on the **Transportation** and **Water sectors** in Texas.

Goal: **Quantify** the *interrelations* and *trade-offs* between the **water**, **energy**, and **transportation** sectors under different *scenarios*

Scenario Outputs:
*Economic Indicators
- Added value to economy
- Energy production
- Infrastructural deterioration

*Social Indicators
- Job Creation
- Traffic
- Health Impact

*Environmental Indicators
- Water Need
- Water Consumed
- Water Degradation
- Soil Degradation
- GHG Emissions
- Air Pollution



Source: TWDB, Rail Road Commission, and authors calculation

Water Programs

Sample Scenarios & Analysis

Scenario Inputs:
- Year evaluated
- Level of fracking activity
- Fracking fluid technology
- Onsite vs. Offsite water source
- Transport of produced gas/oil
- Produced water treatment
  - Onsite vs. Offsite
- Produced water disposal
  - Onsite vs. Offsite

Scenario 1
36% increase in fracking

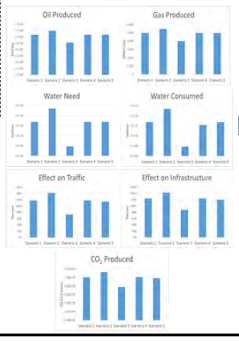
Scenario 2
50% increase in fracking

Scenario 3
10% increase in fracking

Scenario 4
$1 w/ Reuse all Water

Scenario 5
$1 w/ Water Source 50%on/50%off

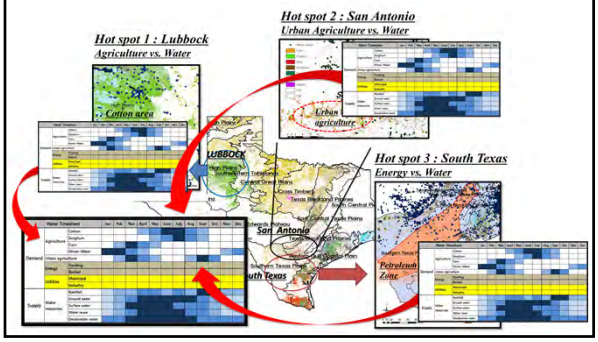
Trade-off Analysis



Sustainability Index

Water Programs

Spatial & Temporal Water Management



Water Programs

Concluding Remarks

- Bridging the water gap requires **multi-stakeholders** approaches
- No silver bullets solutions. Water levers are:
  - **local**
  - **spatially** biased
  - **temporally** biased, yet **Holistic**

WEF Nexus Tool 2.0
The Resource Management Strategy Guiding Tool

WATER AND ENERGY WORKSHOP:
UNDERSTANDING IMPACTS AND TRADE-OFFS TO FACILITATE TRANSITIONS
James A. Baker III Hall, Rice University

May 2015
14
REGISTER NOW

Water Programs

Additional Water Programs

- Texas Water Resources Institute and its projects are well known to TWDB
- TAMUS faculty were offered the opportunity to share information about their activities with TWDB. Their slides are attached as a resource.
- AgriLife Research and Extension Service have numerous programs focused on water conservation and water use efficiency

Thank you for this opportunity to highlight ongoing TAMUS activities intended to meet Texas' water resource challenges.

For further information contact:
Stephen W. Searcy
Biological and Agricultural Engineering
979-845-3940, s-searcy@tamu.edu

Water Programs

Texas Water Resources Institute

Designated Water Resource Research Institute for Texas in 1964

- **Priority areas:**
  - **Restore** water quality
  - **Conserve** water supplies
  - **Educate** professionals, students, and public

- **Conservation activities:**
  - Ag water conservation
    - Ogallala Aquifer Program
    - Lower Rio Grande Valley RCPP
  - Urban water conservation
    - Advanced Metering
  - Statewide outreach
    - txH2O, *Conservation Matters*
  - Engagement
    - Water Cons. Advisory Council
    - Brazos G RWPG
    - Brazos BBASC
    - Texas GW Protection Committee

Research Activities

Water Programs

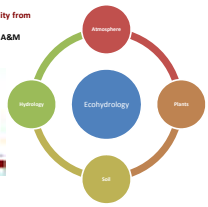
Dr. Georgianne Moore

Associate Professor of Ecohydrology
http://agrilife.org/gmoore/research/

ECOSYSTEM SCIENCE AND MANAGEMENT

MOORE LAB ECOHYDROLOGY

Characterization of Tree Mortality from the 2011 Texas Drought
Funded by NASA and the Texas A&M Forest Service
Project location: Statewide



Hydrologic and Plant Community Response to Extreme Drought and Wildfires
Funded by Texas Parks and Wildlife
Project locations: Bastrop and College Station

Hydrologic Response to Woody Plant Encroachment and Invasive Species
Funded by USDA, DOE
Project locations: Rio Grande, Pecos, Central Texas

Improving Land-Surface Modeling of Evapotranspiration Processes in Tropical Forests
Funded by DOE Climate Science Program
Project location: Costa Rica

Water Programs

Dr. Clyde Munster, P.E.
Professor / BAEN Dept.
Texas A&M University

- Expertise
  - Drought modeling / climate variability
    - Decision making tool for farmers / ranchers
  - Hydrologic modeling
    - Watershed scale simulations for water quality
  - Non-point source water quality
    - Land application of agricultural wastes
    - Onsite Sewage Facilities (OSSFs)

Water Programs

TEXAS A&M AGRILIFE RESEARCH

Hydrology & Water Resources Management

Zhuping 'Ping' Sheng, Ph.D., P.E., P.H., Professor
Texas A&M AgriLife Research Center at El Paso
zsheng@ag.tamu.edu

- Irrigation efficiency and ET monitoring
- Water resources database and decision support system
- Surface water model for Rio Grande flood control, ESA & water operations planning
- Groundwater Models:
  - Transboundary Aquifer Assessment
  - Far West Texas Regional Water Planning
  - High Plains Hydro-Econometric Assessment

Water Programs

TEXAS A&M AGRILIFE RESEARCH

Water Conservation in Urban Landscape & Agriculture

Genhua Niu, Ph.D., Assoc. Professor
Texas A&M AgriLife Research Center at El Paso
gniu@ag.tamu.edu

- Identification of salt and drought tolerant plants (ornamentals, vegetables, crops, fruit trees, etc.)
- Alleviation of stressful environments through sustainable practices (soil amendments, irrigation management, Mycorrhiza fungus, etc.)
- Use of alternative waters (reclaimed water, brackish groundwater, etc.) to irrigate crops and landscapes
- Plant production under controlled environments

Water Programs

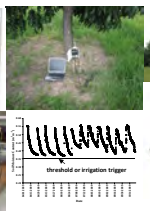
TEXAS A&M AGRILIFE RESEARCH

Water, Salinity and Conservation Management

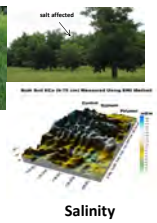
Girisha Ganjegunte, Ph.D., Associate Professor
TX A&M AgriLife Research Center at El Paso
gkganjegunte@ag.tamu.edu

Reuse of Industrial Wastewater

Reducing Wastewater Salinity by Ammonium removal



On-farm Conservation using Sensors



Salinity Assessment and Management at Field Scale

Water Programs

TEXAS A&M AGRILIFE RESEARCH

Water Resources Economics and Policy Analysis

Ari M. Michelsen, Ph.D., Professor and Center Director
Texas A&M AgriLife Research Center at El Paso
amichelsen@ag.tamu.edu

- Water resources quantity & quality valuation
- Economic impacts of alternative strategies & policy responses to prolonged and severe drought
- Agricultural & urban conservation program effectiveness
- Integrated Water Resources Management hydro-economic models & decision support systems
- Water use and value in energy production

Water Programs

Water Conservation Projects at Amarillo AgriLife Research and Extension Center

- Irrigation Water Management – T. Marek
- Regional Water Planning – T. Marek, S Amosson
- ET Network and Calculator – T. Marek, D. Porter
- Open-lot Dairy Water Use – K. Casey

Water Programs

Water Conservation Projects at Vernon AgriLife Research and Extension Center

- Tillage and Water Conservation – P. DeLaune, S. Park
- Hydrology, Watershed Management and Water Quality – S. Ale

Water Programs

Tools for irrigation Management: Weather Station Networks, Soil Water Sensor Monitoring




Juan M. Enciso, Texas A&M AgriLife Research and Extension Center – Weslaco

Water Programs

Bruce A. McCarl, distinguished professor, Dept. of Ag. Econ., mccarl@tamu.edu, http://agecon2.tamu.edu/people/faculty/mccarl-bruce

Expertise: applying regional/national models to study economic, agricultural, urban and environmental Implications of water transfers, water available, El Nino, climate change and strategy

Products:

articles, IPCC assessment reports, National Academies report, USGCRP assessment, EPA reports

Water Programs

Ron Griffin, water resource economist, Dept. of Ag. Econ., ron-griffin@tamu.edu, http://ron-griffin.tamu.edu

Expertise: urban pricing, water marketing, water policy, demand analysis, valuation, cost-benefit analysis

Example products:

Griffin, Ronald C. 2016 (in press). *Water Resource Economics: The Analysis of Scarcity, Policies, and Projects*. 2nd ed. Cambridge, MA: MIT Press.

Griffin, Ron and Sheila Olmstead. 2014. "SWIFT Water Plan Must Make Us Pay." *Austin American-Statesman*, p. A8, April 2.

Griffin, Ronald C. 2012. "The Origins and Ideals of Water Resource Economics in the U.S." *Annual Review of Resource Economics* 4: 353-77.

Griffin, Ronald C., editor. 2011. *Water Policy in Texas: Responding to the Rise of Scarcity*. Washington, D.C.: Resources for the Future.

Water Programs

James Mjelde, natural resource economist, Dept. of Ag. Econ., j-mjelde@tamu.edu

Expertise: dynamic analysis of natural resource issues, energy economics

Example products:

Olsen, K., J.W. Mjelde, and D.A. Bessler. 2014. "Integration among the Canadian and United States Natural Gas Markets." *Annals of Regional Science* 54: 117-142. (DOI) 10.1007/s00168-014-0648-7.

Amatya, R., J. Wight, J.W. Mjelde, and F. Hons.2014. "Sustainable Bioenergy Sorghum [Sorghum bicolor (L). Munch.] Production for Biofuel and its Net-Returns." *BioEnergy Research* 7(4): 1144-1154.2014. Digital Object Identifier (DOI) 10.1007/s12155-014-9451-7

Griffin, R.C. and J.W. Mjelde. 2011. "Distributing Water's Bounty." *Ecological Economics* 72(15 December): 116-128.

Griffin, R.C. and J.W. Mjelde. 2000. "Valuing Water Supply Reliability." *American Journal Agricultural Economics* 82(May): 414-426.

Water Programs

Roger Norton, research professor, Dept. of Ag. Econ. and Director for Latin America and the Caribbean, Borlaug Institute for International Agriculture. Roger.norton@ag.tamu.edu

Expertise: water management policies in developing countries

Example products:

Norton, Roger D. 2004. "Water Management Policies in Agriculture," ch. 6 in: Roger D. Norton, ed., *Agricultural Development Policy: Concepts and Experiences*. London: John Wiley & Sons, Ltd.

Norton, Roger D. 2004. "National Economic Policies and Irrigation in Yemen," appendix in: Roger D. Norton, ed., *Agricultural Development Policy: Concepts and Experiences*. London: John Wiley & Sons, Ltd.

Norton, Roger D. 1974. "Appraisal of Irrigation Projects and Related Policies and Investments" (with L. M. Bassoco and J. S. Silos). *Water Resources Research*. **10**, December.

Norton, Roger D., lead author. 2006. "Improved Management and Conservation of Biodiversity and Critical Watersheds in Panama." Report for USAID/Panama, May.

Water Programs

Luis A. Ribera, international trade and transportation economist, Dept. of Ag. Econ., lribera@tamu.edu

Expertise: international trade, bioenergy, production economics and transportation

Example products:

Enciso, J., John Jifon, Juan Anciso, and Luis A. Ribera. "Irrigation Water Productivity of Subsurface Drip Irrigation versus Furrow Irrigation Systems Using an Internet Based Irrigation Scheduling Program." *International Journal of Agronomy*. Volume 2015 (2015), Article ID 178180, 6 pages.

Ribera, Luis A., and Dean McCorkle. "Economic Impact Estimate of Irrigation Water Shortages on the Lower Rio Grande Valley Agriculture." Texas A&M AgriLife Extension Service. June 2013.

Rodriguez, Hector G., Jennie S. Popp, Luis A. Ribera, Indrajeet Chaubey, and Brian Shaffer. "Implementation of Best Management Practices Under Cost Risk to Control Phosphorus Pollution in a Crop Based Watershed in Arkansas." *Journal of Environmental Monitoring and Restoration*. 3 (2007):195-207.

Water Programs

Ed Rister, The M. Edward Rister '74 Chair in Rural Entrepreneurship, Dept. of Ag. Econ., e-rister@tamu.edu

Expertise: economics of: BMPs for mitigating water quality issues, BMPS for irrigation districts, and potable water sources/treatment methods

Example products:

Lee, T., M.E. Rister, B. Narashimhan, R. Srinivasan, D. Andrews and M.R. Ernst. 2010. "Evaluation and Spatially Distributed Analyses of Proposed Cost-Effective BMPs for Reducing Phosphorous Level in Cedar Creek Reservoir, Texas." *Transactions of ASABE* 53 (5): 1619-27.

Rister, M.E., R.D. Lacewell, and A.W. Sturdivant. 2007. "Economic and Financial Costs of Saving Water and Energy: Preliminary Analysis for Hidalgo County Irrigation District No. 2 (San Juan) – Replacement of Pipeline Units I-7A, I-18, and I-22." Texas Water Resources Institute. TR-303.

Rister, M.E., C.S. Rogers, R.D. Lacewell, J.R.C. Robinson, J.R. Ellis, and A.W. Sturdivant. 2009. "Economic and Financial Methodology for South Texas Irrigation Projects - RGIDECON©." Texas Water Resources Institute TR-203 (Revised).

Sturdivant, A.W., C.S. Rogers, M.E. Rister, R.D. Lacewell, J.W. Norris, J. Leal, J.A. Garza, and J. Adams. 2007. "Economic Costs of Desalination in South Texas: A Case Study." *Journal of Contemporary Water Research and Education* 137 : 21-39.

Water Programs

Ron Lacewell, water resource economist, Dept. of Ag. Econ., r-lacewell@tamu.edu

Expertise: water planning (Texas Water Plan for region E and M), water in hydraulic fracturing, biological control of Arundo, benefit/cost of flood control, water conservation strategies for irrigation districts and on farm, policy

Example products:

Economics in Water Planning (Presentation for Water Summit in Austin (5/19/2014-co with Ari Michelsen)

UCOWR Panel (Texas v. New Mexico Supreme Court Water Case: Process, Issues and Interpretation)

Adusumilli, Naveen, Taesoo Lee, M. Edward Rister, and Ronald D. Lacewell. 2014. "The Economics of Mitigation of Water Pollution Externalities from Biomass Production for Energy." *Resources* 3: 721-733; doi: 10.3390/resources 3040721

Black & Veatch. 2015. Contract, Region M, water conservation strategies for agriculture.

Allen, Thomas. 2014. "Water Value and Environmental Implications of Hydraulic Fracturing: Eagle-Ford Shale." Outstanding Texas A&M University Undergraduate Thesis for 2014.

Water Programs

Lucy Camacho
Environmental Engineering Department
Texas A&M University - Kingsville

Desalination, Water Treatment and Concentrate Management
Electrodialysis/Electrodialysis Metathesis Technology
Zero-discharge desalination and minerals recovery

Research focus areas
•Desalination of brackish, and salty water.
•Separation of trouble chemicals.
•Recovery of minerals with marketing value.
•Hybrid RO/ED, RO/ED/EDM systems for ZDD.

Laboratory Equipment
•Semi-pilot, portable-compact MD unit.
•Capacity: 0.5-1.0 GPM.
•ED/EDM stack, ion-exchange membranes.

Water Programs

Dr. Jaehak Jeong (jeongj@tamu.edu)
Blackland Research & Extension Center, BAEN

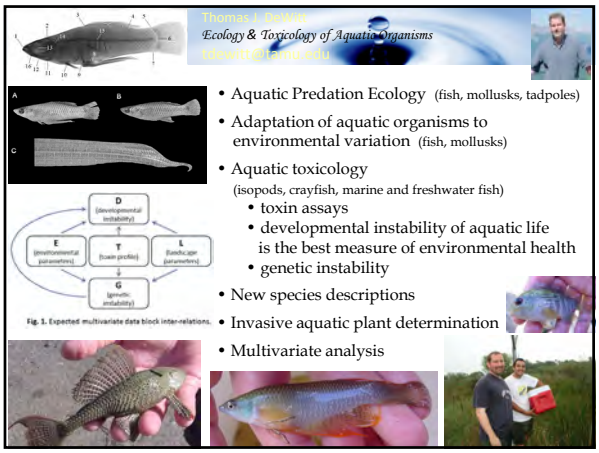
Research Interests: Water availability and water quality assessment for water and food security and environmental sustainability under rapid urbanization and climate change– (SWAT and APEX model development and assessment)

Assessment of Water Resources Conservation using Hydrologic Simulation models

- **Urban Stormwater Management** - Modeling (Sponsored by City of Austin)
- **Effects of Urbanization and Climate Change in Urban Stream** Health (Sponsored by EPA R6)
- Small-Scale **Irrigation Technology for Farmers** in Water Scarce African Countries (Sponsored by USAID)
- **Water Availability Assessment** for Maui Island using integrated SWAT and MODFLOW (USDA)

Environmental Sustainability of Agricultural Practices in Croplands

- **National Assessment of the USDA Conservation Program for Improving Water Quality** (USDA-NRCS)
- **Feasibility of Bioenergy Crop Production** in Hawaii: Water Availability and Environmental Sustainability Assessment (US Navy and USDA)
- **Best Management Practices for Agricultural NPS** in Korea (RDA, Korea)
- **Watershed Protection Plan** for Bacteria TMDL in Arroyo Colorado (TCEQ)



Water Programs

Masami Fujiwara
Coastal Marine Fisheries

- Research Interest
  - Use of modern statistical analyses and mathematical modelling to understand population dynamics of penaeid shrimp and other species of economic and/or conservation interest
- Current Research Topics
  - Evaluation of the effects of river discharge on juvenile penaeid shrimp production
  - Investigation of the effects of coastal marsh conditions on juvenile penaeid shrimp survival and growth
  - Analyzing predator-prey interactions between juvenile penaeid shrimp and economically important fish species
  - Bioeconomics of coastal marine fisheries

Water Programs

Delbert M. Gatlin III
Aquaculture and Fish Nutrition

- Research topics with prominent species such as channel catfish, hybrid striped bass, red drum, penaeid shrimp and tilapia include:

- Determining nutrient requirements and metabolism
- Developing and evaluating novel feed ingredients
- Evaluating dietary effects on immune responses and disease resistance

Water Programs

Frances Gelwick
Fisheries Management Research

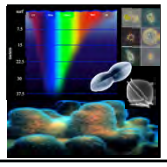
- Research topics in fisheries management:
- Hydrological and seasonal influences on stream fish assemblages, including macroinvertebrate prey resources and parasite infestations
- Comparative reproductive behaviors of wild and hatchery populations of native Guadalupe Bass (Texas State Fish) relevant to supplementary stocking efforts by TPWD to reduce effects of hybridization with non-native Smallmouth Bass
- Evaluating the role of newly established native vegetation in reservoirs including food web dynamics, growth and body condition of prey- and sport-fishes, and assemblage composition of their invertebrate prey and phytoplankton species.

Water Programs

Research in the
Roelke Aquatic Ecology Lab

In Texas

- Harmful algal blooms, inland and coastal – ecology and mitigation
- River inflows to lakes and bays – ecosystem health



International

- Red Sea (Saudi Arabia) - Impacts of aquaculture and desalinization on ecosystem structure and function
- Aegean Sea (Greece) – ocean circulation, nutrient loading and ecosystem functioning
- Inland lakes (Israel and Singapore) – alternative stable states and implications for management

Extension & Outreach Activities

Water Programs

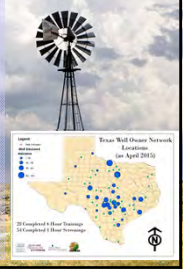
TEXAS WELL OWNER NETWORK

PROTECTING GROUNDWATER RESOURCES & HUMAN HEALTH

Impacts

6 month follow-up survey:

- 71% of participants with wells near contamination sources (pet shelters, livestock yards, etc.) had moved the sources.
- 89% of those needing to clean out hazards from their well house had done so.
- 55% of participants with septic tanks that needed pumping had pumped their septic tanks at no public expense.
- 38% of participants who needed to had plugged or capped their unused/deteriorated wells at no public expense.
- 74% shared the resources/materials with others who were not at the training.

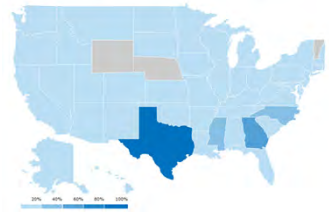


Water Programs

40 GALLON CHALLENGE

TEXAS A&M AGRILIFE EXTENSION

WATER CONSERVATION PLEDGE: **40gallonchallenge.org**



Impacts:

- 60% increase in residential water availability
- 3600 Texas pledges to date
- 240 million gallons saved annually to date
- 6-month follow-up indicated 84% of participants followed through on 75-100% of their pledge

Water Programs

EARTH-KIND® ENVIRONMENTAL LANDSCAPE MANAGEMENT

- The Texas A&M Department of Horticultural Sciences' Earth-Kind Program yields highly significant water savings, while also protecting air and water quality by greatly reducing the need for fertilizers and pesticides on landscape plants.
- Based on years of research in several states, Earth-Kind Roses provide a:
  - **70% reduction in irrigation**
  - **Total elimination of fertilizers**
  - **Total elimination of pesticides on the plants**
- Earth-Kind Roses have become, to our knowledge, the fastest growing and most popular university program of its kind in the nation.

Water Programs

Dana Osborne Porter, Ph.D., P.E.

Associate Professor and Extension Agricultural Engineering Specialist, Texas A&M AgriLife Research and Extension Center – Lubbock
Research Program Leader and Associate Department Head, Department of Biological and Agricultural Engineering

Integrated Applied Research and Technology Transfer to Promote Efficient Irrigation and Water Management in Agriculture

Objectives:

- develop, evaluate and promote appropriate application of advanced agricultural irrigation technologies, irrigation management tools and best management practices;
- improve quality and value of agricultural research programs through technical support to improve understanding of irrigation technologies, BMPs and related crop water management concepts; and
- provide relevant educational resources and opportunities for traditional and emerging audiences through irrigation workshops; agricultural conferences; individual contacts and mentoring; and print, electronic and mass media delivery.

Stakeholders: agricultural producers; landowners; crop consultants; agribusiness and associated professionals; agricultural and natural resources agency professionals; irrigation, environmental and engineering professionals; extension and research professionals.

Water Programs

Texas Watershed Steward Program

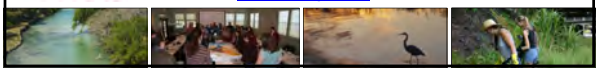
- Course Description: No-cost, half-day introductory training in the fundamentals of watersheds and watershed management with the purpose of increasing citizen awareness and involvement in the stewardship of Texas' water resources.
- Target Audience: Individuals representing all stakeholder groups: Agriculture; urban; business/industry; city/county officials and personnel; landowners; and homeowners
- Extras: Earn continuing education credits at no cost (ex: P.E., Certified Crop Advisor, Certified Planner, etc.), and receive free course materials including multiple water-related publications.

TEXAS A&M AGRILIFE EXTENSION

http://tws.tamu.edu/

Michael Kuitu: 979-862-4457
michael.kuitu@ag.tamu.edu

TEXAS Watershed Steward



Water Programs

Watershed Protection Planning

- Stakeholder driven, non-regulatory approach for addressing surface water quality issues in Texas. Got it.
- Utilized to protect healthy waters and restore impaired waters.
- Facilitates the implementation of Best Management Practices by providing technical and financial assistance to stakeholders.

TEXAS A&M AGRILIFE EXTENSION | SOIL & CROP SCIENCES TEXAS A&M UNIVERSITY | TEXAS A&M AGRILIFE RESEARCH

Water Programs

Rainwater Harvesting

- County Extension Agents
- Master Gardener Specialist
- Professionals
  - Certification
  - CEUs
- Homeowners
- Livestock
- Wildlife
- Potable
- Firefighting

Kaufman County Demonstration

Water Programs

Steve Amosson, extension management economist-Amarillo, samosson@ag.tamu.edu

Expertise: water policy, demand analysis, valuation, cost-benefit analysis

Example products:

Amosson, S. H., B. Guerrero, and H. Graham. 2014. "The Economic Impact and Water Use of the Small Grains Industry in the Southern Ogallala Region." September. AG-012, Texas A&M AgriLife Extension Service.

Amosson, S. H., B. Guerrero, and H. Graham. 2014. "The Economic Impact and Water Use of the Feed Grains Industry in the Southern Ogallala Region." 2014. AG-011, Texas A&M AgriLife Extension Service.

Amosson, S. H., S. Nair, T. Marek, D. Jones, J. Yates, B. Guerrero, and M. Jones. 2014. "2015 High Plains Irrigated Crop Profitability Analyzer." December. Texas A&M AgriLife Extension Service.

Amosson, S., L. Almas, J Girase, N Kinney, B. Guerrero, K Vimlesh and T. Marek. 2011. "Economics of Irrigation Systems." October. B-6113, Texas AgriLife Extension Service.

Water Programs

David P. Anderson, livestock and food products marketing, Dept. of Ag. Econ., danderson@tamu.edu

Expertise: livestock and dairy economics, ag. policy, economic impact of drought

Example products:

Anderson, D.P., J.M. Welch, and J.R.C. Robinson. "Agricultural Impacts of Texas's Driest Year on Record." *Choices*. Third Quarter, 2012.

Anderson, D.P. "Cattle and Calf Prices Recover a Little After the Shock of Drought." *Ag. Monthly*, October, 2012.

Falconer, L. and D.P. Anderson. "The Impact of the 2011 Drought on the Cattle Industry in South Texas and Outlook for Recovery." Texas AgriLife Extension Service. April 19, 2012.

Anderson, D.P., J. Robinson, J.M. Welch. "2011 Crop and Livestock Drought Losses Top $7.6 Billion; Commercial Timber Losses add Another $669 Million." March 22, 2012.

Water Programs

Tiffany Dowell Lashmet, assistant professor & extension specialist – agricultural law, Dept. of Ag. Econ. tdowell@tamu.edu

Expertise: legal issues impacting landowners including Texas water law.

Example products:

Dowell, Tiffany, 2014. *You Can Lead Livestock to Water…A Survey of Exempt Livestock Wells in the West*, 17 U. Denv. Water L. Rev. 1.

Richardson, Jesse and Tiffany Dowell, 2012. *The Implication of Bounds v. State of New Mexico*, J. of Contemporary Water Research and Educ.

Dowell, Tiffany, 2013. *Texas Water: Basics of Groundwater Law*, Texas Agriculture Law Blog, http://agrilife.org/texasaglaw/2013/10/22/texas-water-basics-of-groundwater-law/.

Dowell, Tiffany, 2013. *Texas Water Wars: Texas v. New Mexico*, Texas Agriculture Law Blog, http://agrilife.org/texasaglaw/2013/09/18/texas-water-wars-texas-v-new-mexico/.

Water Programs

Rob Hogan, district economist and management specialist, Dept. of Ag. Econ., Rhogan@ag.tamu.edu, http://agecoext.tamu.edu/

Expertise: water policy, drought mitigation, demand analysis

Example product:

Borisova, Tatiana, Steve Amosson, Tracy Boyer, Rob Hogan, Bridget Guerrero, John Michael Riley, Jeff Mullen, Larry D. Sanders, Amanda Smith, Nathan Smith, Bradley Watkins, John Westra, David Willis. 2015. The Future of Water Resources in the South: Challenges and Potential Solutions. Invited Symposium at the annual meeting of Southern Agricultural Economics Association. Atlanta, GA.

Water Programs

Jason Johnson, extension economist, Dept. of Ag. Econ., jljohnson@tamu.edu; (254) 968-4144

Expertise: cost-benefit analysis, assessment of best management practices, agricultural water demand analysis

Example products:

Johnson, Jason L. 2014. *A Benefit-Cost Analysis of Texas Weather Modification Activities Resulting in an Additional One Inch of Rainfall Across a Region*. Report submitted to West Texas Weather Modification Association, et al..

Lambert, Barry, Kelly Hibbeler, DeeAndra L. Lambert, Jason L. Johnson, Larry Beran, and James Marsh. 2013. *Recovery Potential Screening Tool Analysis for Specified Segments in the Trinity River Basin*. Texas A&M AgriLife Research Report submitted to Texas Commission on Environmental Quality, Contract No. 582-9-90439.

Johnson, Jason L., Clint Wolfe, and David Waidler. 2012. *An Economic Assessment of Water Quality Improvement BMPs for the Eagle Mountain Lake Watershed*. 2012 Agricultural and Applied Economics Association Meetings, August 12-14, 2012, Seattle, Washington.

Taesoo Lee, Jason L. Johnson, Raghavan Srinivasan. 2011. *Cost Effective Multiple BMPs to Reduce the Total Phosphorous Level in a Reservoir*. 2011 International Soil and Water Assessment Tool Conference, University of Castilla La Mancha, June 15 - 17, Toledo, Spain.

Water Programs

Richard Woodward, professor, Dept. of Ag. Econ., r-woodward@tamu.edu

Expertise: water quality policy

Example products:

Newburn, David and Richard T. Woodward. 2012. "An Ex Post Evaluation of the Great Miami Water Quality Trading Program." *Journal of the American Water Resources Association.* 48(1): 156–169.

Woodward, Richard T. 2011 "Double Dipping in Environmental Markets" *Journal of Environmental Economics and Management*. 61(2):153-169

Woodward, Richard T. and W. Douglass Shaw. 2008. "Allocating Resources in an Uncertain World: Water Management and Endangered Species" *American Journal of Agricultural Economics* . 90(3):593-605.

Woodward, Richard T., Ronald A. Kaiser and Aaron-Marie Wicks. 2002. "The Structure and Practice of Water-Quality Trading Markets." *Journal of the American Water Resources Association*. 38:967-979

Water Programs

Si-Wi: Sustainable and Integrated Water Infrastructure

- Education, Demonstration, and Training Programs to encourage:
  - Reuse/Multiuse,
  - Decentralization, and
  - Desalination

  for bridging the gap between projected water demand and existing water supply in Texas (The Water Gap).
- SWIPES – Sustainable Water Infrastructure Planning and Evaluation System, a computer system proposed as one of the tools to promote **Si-Wi**.

Dr. Anish Jantrania • Texas A&M AgriLife Research & Extension • Blackland Research & Extension Center • ajantrania@tamu.edu • 254.774.6014

Water Programs

Aquaculture & Fisheries Extension- Todd Sink

- Aquaculture production practices and methods
- Farm pond management
- Aquatic vegetation management
- Aquaponics food production
- Water chemistry analysis and amendments for fish

Water Research and Expertise Texas Tech University Ready to Serve Texas' Water Challenges

Danny Reible •Tom Arsuffi • Ken Rainwater
Texas Tech University

TWDB 4/29/15

Water Focused Research Activities

More than 100 faculty

- **College of Agriculture Science and Natural Resources Water Center** investigates water management and policies regarding agricultural and urban landscape water use
- **Department of Environmental Toxicology's Institute of Environmental and Human Health** examines the environmental impacts of toxic chemicals and human health consequences
- **Water Resources Center** encourages, conducts, and coordinates water resources and environmental engineering research
- **Llano River Field Station** develops water and watershed related research, education, and engagement efforts in the Texas Hill Country
- **Climate Science Center** serves as the regional hub for climate change, providing expertise on linking regional climate projections to agricultural production, ecosystem services, water policy and planning, and sustainability of natural and agro-ecosystems
- **Center for Geospatial Technology** applies geographic information systems to map and analyze the distribution and depletion of groundwater in the Ogallala Aquifer in and beyond Texas, as well as related demographic impacts
- **School of Law's Center for Water Law and Policy** assesses legal, regulatory, institutional, and policy aspects of water use, allocation, regulation, and conservation
- **International Center for Arid and Semiarid Land Studies** promotes and facilitates multidisciplinary initiatives in research, education, and regional development programs

Supporting Activities

Examples

- National Academy of Sciences evaluation of Edwards Aquifer Authority Habitat Conservation Plan 2013-2017 (D. Reible, Chair)
- Science Committee, Edwards Aquifer Authority (T. Arsuffi)
- SB3 Nueces River – Basin and Bay Expert Science Team (T. Arsuffi)
- Llano River Watershed Protection Plan (T. Arsuffi, K. Rainwater)
- Water Supply Enhancement Program, TSSWCB (K. Rainwater)
- Regional Water Planning Committee (K. Rainwater, Region O)
- Integrated wind-water desalination demonstration (K. Rainwater)
- The Academy of Medicine Engineering and Science of Texas Water Summits in 2012, 2014 (D. Reible, Chair)
- National Science Foundation, Food, Energy, Water Workshop initiative for Southern High Plains (D.Reible)

Agenda

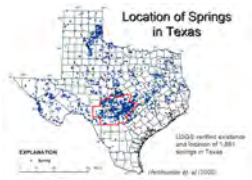
Selected campus activities

- Tom Arsuffi
  - Llano River Field Station
  - Invasive species
  - Land stewardship
  - Protecting healthy watersheds
- Ken Rainwater
  - Texas Alliance for Water Conservation and CASNR
  - Recent TWDB Research Projects by Water Resources Center
  - Regional drinking water concerns
  - Support for regional water management districts
- Danny Reible
  - Food Energy Water (FEWs) Initiative
  - Water management for oil and gas activity
  - Water for future population and economic growth

Llano River Field Station

Connections Upstream and Downstream

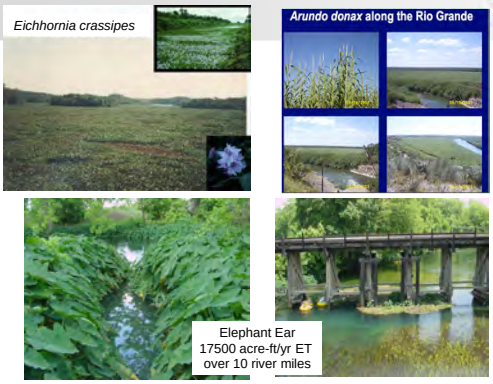
- Unique Location
  - Springs, headwaters of five river systems
- Land Stewardship
  - Brush control
  - Drought planning and response
- Aquatic Invasive Species
- Stream Ecosystem Health
- Unique Partnerships
- Engagement, Outreach, and Natural Resource Literacy



Increasing Water Supplies

- Non-traditional Strategies
  - Conjunctive use of groundwater and surface water
  - Brush control
  - Interbasin transfer
  - Desalination
  - Weather modification
  - Rainwater catchment and graywater systems
  - *Invasive species mitigation*
    - Need synthetic analysis of ecology and impacts on ecosystem goods and services
    - Several countries consider invasive species control and management a water conservation strategy
    - $120 billion per year in environmental and public health damages in the USA (Pimentel et al. 2007)

Example Invasive Species



Protecting Healthy Watersheds – Benefits

- Decreases
  - Flood risk
  - Regulatory compliance costs
  - Drinking water treatments cost
  - Health care cost
  - Stormwater infrastructure cost
- Increases
  - Property values
  - Tourism and recreation spending
    - Guadalupe bass – $143 M/yr angler spending, 776 jobs
  - Timber and farm production
  - Nutrient cycling, carbon storage
  - Biodiversity, wildlife movement corridors
  - Water storage
  - Micro-climate regulation

Current Market System

How we value ecosystem services

- Healthy watersheds provide ecosystem services at little to no cost
- Systems are under-valued, their roles misunderstood
- Services provided by intact watersheds are costly to replicate (if possible)
- Conservation of healthy watersheds is a wise investment, and also provides a variety of monetary and non-monetary benefits

Development of Upper Llano River Watershed Protection Plan

- Empowering local stakeholders
- Characterizing current water quantity and quality conditions
- Analyzing watershed data using eco-hydrologic models
- Increasing education among the targeted audience
- Funded by Environmental Protection Agency and Texas State Soil and Water Conservation Board
  - Healthy Watersheds Initiative
- Collaboration with Texas Water Resources Institute

Texas Alliance for Water Conservation

College of Agricultural Science and Natural Resources

- Leaders: Chuck West, Others in CASNR
- Funded by the Texas Water Development Board
  - Phase 1 – 2005-2013
  - Phase 2 – 2014-2020

Texas Water Development Board

Producers of Hale & Floyd Counties

FARM Assistance

Texas A&M AgriLife Extension

USDA NRCS & ARS

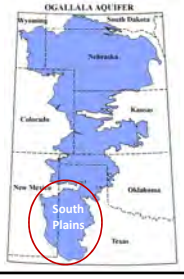
Texas A&M AgriLife Research

HPWD High Plains Underground Water Conservation District

Texas Tech University College of Agricultural Sciences & Natural Resources

Objectives of TAWC

- Identify and communicate technologies
- Provide planning aids
- Sustain agriculture in the South Plains of the Ogallala Aquifer region



Phase 1 Accomplishments

- Demonstrated how to increase water use efficiency with decision aids
- Compared profitability of crop and irrigation options
  - ✓ Enterprise budgets
  - ✓ Field testing of technology
- Got out the message with meetings and electronic media
- Wide recognition for educational efforts



Phase 2 Emphasis

- Expanded counties
- Reduce irrigation to 75% of potential ET
  - ✓ Monitoring soil water content
  - ✓ New precise irrigation techniques
- Water College, training crop consultants
- Advanced online tools
  - ✓ http://tawc.us

Technology Comparison and Demonstration

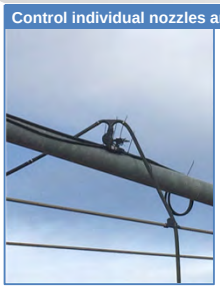

Spray | PMDI | LEPA

Comparisons of different water application configurations

Variable Rate Technology

Delivers right amount of water where needed

Control individual nozzles and speed of pivot




CASNR Departments

Emphases on Water Expertise

- Plant & Soil Science
  - ✓ Drought-tolerant crops, water-use efficiency, irrigation and grazing management
- Natural Resource Management
  - ✓ Watershed management for water yield and grazing, wetland and stream conservation
- Agricultural and Applied Economics
  - ✓ Economic consequences of farm/ranch policies and practices
- Animal and Food Sciences
  - ✓ Low-water cattle grazing and feeding
- Landscape Architecture
  - ✓ Xeric landscape designs, erosion control

Recent TWDB Research Projects

Water Resources Center

- Demonstration a High Recovery and Energy Efficient RO System for Small-Scale Brackish Water Desalination
  - ✓ L. Song, B. Schuetze, K. Rainwater (2012)
  - ✓ Novel flow circulation system
- Assessment of General Circulation Models for Water-Resources Planning Applications
  - ✓ S. Tummuri, D. Thompson, K. Rainwater (2013)
  - ✓ Identify GCMs for downscaling for Texas regional water planning
- An Integrated Wind-Water Desalination Demonstration Plant for an Inland Municipality
  - ✓ K. Rainwater, L. Song, T. Lehman, and J. Schroeder (2015 pending)
  - ✓ Deployed at Seminole, Gaines County, Texas

Drinking Water Quality Issues

Preliminary work underway with TCEQ

- Many non-compliant groundwater-dependent systems
  - ✓ Arsenic, fluoride, radionuclides, TDS, other solutes
  - ✓ Previously only disinfection, now advanced treatment
  - ✓ Engineering feasibility and pilot studies currently required (typical cost $100,000 to $300,000)
    - TCEQ, TWDB, and others cooperated to allow permits for reverse osmosis for TDS only based on vendor modeling
    - Dozens of small cities and community water systems now need updates for compliance
- Possible solution – group non-compliant systems based on capacity and target contaminants
  - ✓ Share feasibility study costs and vendor information
  - ✓ Perform fewer pilot studies at central location with different source waters
  - ✓ Potential for third-party service providers

Regional Water Management

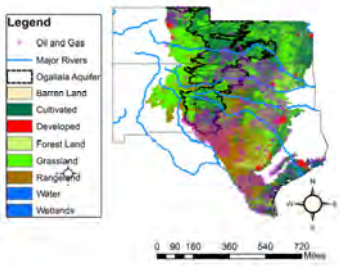
Opportunities

- Drought-inspired public awareness of conservation
- Recognition of shared surface water and groundwater supplies
- Economies of scale can affect cost of water/volume
- Public or private sources of capital
- Spread capital and O&M costs over larger populations
- Provide highly skilled treatment system operators
- Interdisciplinary cooperation to integrate consideration of energy for water treatment and transmission
  - ✓ Energy and water equipment vendors may not see synergy
  - ✓ Researchers can work with consultants to conceive and analyze alternatives

Food Energy Water Nexus

Southern Great Plains

- **Agriculture**
  - ✓ 80% of consumptive water use in US
  - ✓ Historical community economic foundation
- **Growing pressure from population and high value economy (i.e. energy economy)**
- **NSF proposal building on "Big 12" water summit**



Water Resources Center

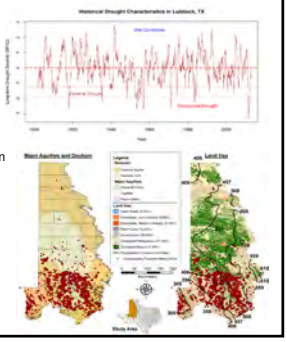
Director, Venki Uddameri

Assessment of Brackish Water Resources in West Texas
- Understand geochemical evolution
- Ways to reduce freshwater footprint in Ogallala
- Current efforts focused on Dockum group of sediments

Reuse of Produced Water from Oil and Gas Operations
- Chemical characteristics of produced water
- Thermodynamic modeling of brine chemistry
- Technologies for cost-effective treatment for reuse in hydraulic fracturing

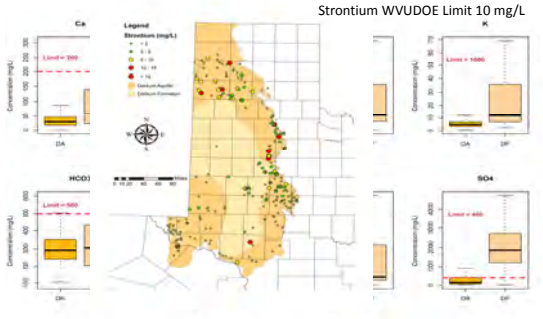
Drought Atlas for the Ogallala Aquifer
- Understand historical drought severity and duration characteristics in West Texas
- How does Ogallala Aquifer respond to droughts?
- Climate change and future drought stresses in the region

Securing Water for Economic Future of Texas
- Feasibility evaluation of very-large scale seawater desalination for creating a 20% water surplus in the State by 2060



Permian Basin Brackish Waters

Strontium WVUDOE Limit 10 mg/L



Climate-Agriculture-Water Interactions

- **Climate Science Center**
  - ✓ K. Hayhoe
- **CASNR**
  - ✓ C. West
- **Water Resources Center**
  - ✓ V. Uddameri
  - ✓ D. Reible

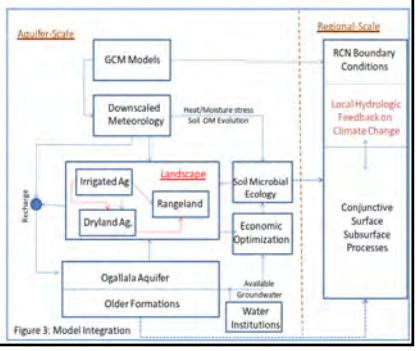
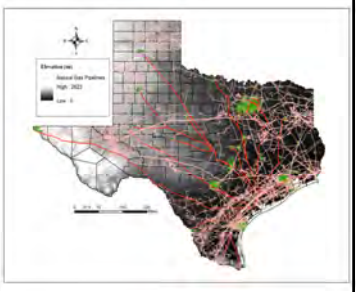


Figure 3: Model Integration

Future State Water Needs

- **Project of 500 MGD (560,000 acre-ft/yr) supply 20% of future needs in central, east TX**
- **Coastal desalination of that magnitude feasible?**
  - Likely for population centers, energy use, manufacturing
  - Would reduce pressure on agriculture and ecological needs in period of drought
- **Conducting preliminary feasibility assessment**



Pipeline easements for transport?

Water Focused Research Activities

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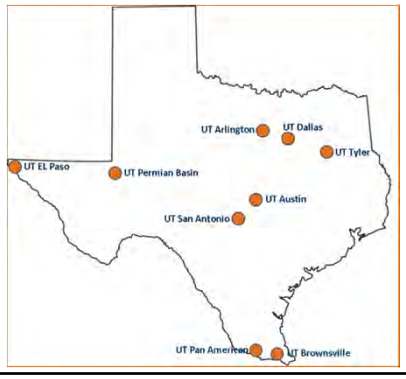
The University of Texas System



Texas Water Development Board

Sustainable Water Research for Texas

The University of Texas at El Paso

April 29, 2015

UTEP Research Centers

Center for Environmental Resources Management

Mission: provide university-wide leadership and coordination for environmentally-related research, education, and outreach activities. Priority areas for CERM include:

- Environmental health
- Water quantity and quality
- Desert and wetland ecology
- Air quality
- Renewable energy

CERM

UTEP Research Centers

Center for Inland Desalination Systems

Mission: CIDS will advance the science, technology, and commercialization of inland desalination and innovative water treatment.

CIDS
Center for Inland Desalination Systems

Sustainable Water Resources

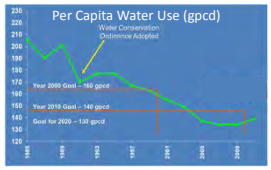
- Irrigated agriculture and growing population in a desert river basin facing climate change:
- **How can sufficient water supplies be achieved and managed sustainably?**
- Integrated modeling among: hydrogeologists, climatologists, ag scientists, engineers, enconomists, anthropologists
- **Stakeholders collaboratively propose potential solutions that will be modeled and piloted**

USDA NSF

Water Conservation

El Paso Water Utilities Public Service Board

- EPWU has strategically invested in a conservation campaign for over two decades
- **Over 250 billion gallons and $460 million of deferred capital**
- Ongoing rate structure analyses



Indirect Potable Reuse

Fred Hervey Water Reclamation Plant (since 1985)

- 12 MGD of **wastewater treated to drinking water**:
  - primary, secondary, biological nitrogen removal
  - lime softening, sand filtration, ozonation, biologically activated carbon filtration, chlorination
- **Aquifer recharge** (Hueco Bolson)
- Analyses of constituents of emerging concern

Direct Potable Reuse

- **Advanced Purified Water**
  - First full-scale direct potable reuse plant in the U.S.
  - Secondary effluent treated by:
    - Biological nitrogen removal
    - Ozonation
    - Membrane Filtration
    - Reverse Osmosis
    - UV-Peroxide AOP
    - GAC Filtration
    - Chlorination
  - Piloting under construction

Brackish Groundwater Desalination

- Kay Bailey Hutchison Desalination Plant
  - 27.5 MGD total product (15 MGD permeate)
  - Two-stage RO
  - 83% recovery
  - Deep-well injection
- **Ongoing research and development of advanced concentrate treatment systems**

Zero Discharge Desalination (ZDD)

- Demonstrated at KBH (El Paso) and BGNDRF (Alamogordo)
- NF/RO and Electrodialysis Metathesis
- **Recovery: 97-99%**
- Energy: 6-7 kWh/kgal
- Potentially recoverable salts: $CaSO_4$, $Mg(OH)_2$, NaCl

Concentrate Enhanced Recovery RO

- Demonstrated at EPWU KBH (El Paso) and BGNDRF (Alamogordo)
- Seawater RO with high cross-flow and short cycle periods
- High silica treatment
- **Recovery: 95-97%**

Water & Wastewater for Colonias

- Focus groups for social sustainability
- Point of Use (POU) treatment for drinking water
- Community organization for development of long-term water and wastewater infrastructure

Water Research at UT Arlington

UNIVERSITY OF TEXAS ARLINGTON

The UTA Urban Water Institute

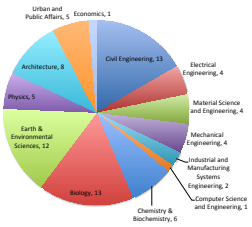
Located at the University of Texas at Arlington in the heart of the Dallas-Fort Worth Metrople
Water Institute has for mission to transl
challenges into opportunities for North
to develop innovative triple-bottom-line
solutions that encompass the economy
environment. Its goals are to

1. Bring together interdisciplinary educ
researchers, agencies, industries ar
2. Innovate and educate in multidiscipl
and sustainable solutions for water and energy, and
3. Help build public-private partnerships

The UTA Urban Water Institute

At The University of Texas at Arlington, about 80 faculty members are involved on various aspects of water research. These faculty members are associated with almost all UTA colleges and schools, including the College of Engineering - Departments of Civil Engineering, Electrical Engineering, Material Science and Engineering, Aerospace and Mechanical Engineering, Industrial and Manufacturing Systems Engineering, and Computer Science and Engineering - College of Sciences, - Department of Earth Sciences, Physics, Chemistry and Bio-Chemistry, and Biology, College of Business, School of Urban and Public Affairs, and School of Architecture.

Director: Jean-Pierre Bardet; bardet@uta.edu 817-271-6586



Collaborative Laboratories for Environmental Analysis and Remediation (CLEAR)

http://clear.uta.edu

Primary Research Areas:

- Exploring the relationship between unconventional drilling (hydraulic fracturing, waste handling, etc.) and groundwater quality.
- Development and testing of advanced remediation strategies for water decontamination.

UNIVERSITY OF TEXAS ARLINGTON

C.L.E.A.R.

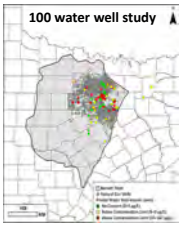
Contact: Kevin A. Schug, Ph.D., Shimadzu Distinguished Professor of Analytical Chemistry, CLEAR Director (kschug@uta.edu)

Groundwater Quality

C.L.E.A.R.

Barnett Shale, 2011

100 water well study



29 of the 91 samples collected with active extraction areas contained elevated levels of arsenic (>10 µg/L)

Fontenot, B. E., et al. *Environ. Sci. Tech.* **2013,** *47*, 10032-10040

Advanced Analytical Methods and Use of Instrumentation in Shimadzu Center for Advanced Analytical Chemistry (www.uta.edu/scaac) for measuring metals, ions (Dasgupta lab, UTA), organics, and general water quality.

Most recent efforts:

Analytical characterization of wastewater from unconventional drilling: Thacker et al., *Water* **2015**, *7*, 1568-1579.

Extended water quality study (550 water wells) in the Barnett Shale: *Submitted for publication, 3/2015*.

Time course evaluation of the onset of unconventional oil extraction in the Cline Shale on water quality: *Submitted for publication 3/2015*.

Remediation Efforts

C.L.E.A.R.

Active Degradation (Academic Affiliates)

- Extremophile enzymes (Pierce lab, UTA)
- Nanoparticle-assisted heterogeneous catalysis (Dias lab, UTA)
- Organocatalytic oxidation (Foss lab, UTA)

Passive Filtration (Industrial Affiliates)

- American Water Recycling (El Paso) – Graphene technology
- Asahi Kasei (California/Japan) – Advanced membrane technology

Drug Disposal Process

- US Patent Filed (Kevin Schug/UT Arlington)
- Licensed to MK Disposal Technologies

UNIVERSITY OF TEXAS ARLINGTON

Flood control

- High-resolution flash flood forecasting in large urban areas (NSF – DJ Seo)
- Hydrologic ensemble forecasting (NOAA/NWS - DJ Seo)
- Hydrologic analysis and design for Fort Worth Floodway (TRWD – N. Fang)

Water quality, municipal solid waste management

- In-situ sensing for detection of biological toxins in harmful algal blooms (NSF, NIH – H. Choi)
- Groundwater quality, wastewater remediation (K. Schug)
- Golden algae in Texas reservoirs (TPWD, J. Grover)
- Real-time watershed and river water quality forecasting (NIER – DJ Seo)
- Design and optimization of leachate recirculation in municipal solid waste (S. Hossain)

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UNIVERSITY OF TEXAS ARLINGTON

Water supply

- Medium- to long-range ensemble streamflow and drought forecasting and decision support (NOAA/CPO – DJ Seo)
- Hydraulic fracturing and its impact on water resources (M. Hu)

Water supply and distribution systems, infrastructure

- Application of monochloramine to control biological growths in pumps and pipes (TRWD – A. Kruzic)
- Epidemiology of urban water distribution systems (JP Bardet)
- Performance of earthfill dams and prevention of surficial failures (USACE – A. Puppala)

GIS and remote sensing

- High-resolution mapping of elevation, vegetation and surface water (J. Lee)

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WIT
Water Institute of Texas

UTSA
The University of Texas at San Antonio™

Water Research Expertise and Interest

UTSA The University of Texas at San Antonio™

Water Institute of Texas (WIT)

- Conduct research on the various factors related to water sustainability and their effect on the health and economic development of Texas and the Southern USA
- Multi-disciplinary collaborative institute that fosters partnerships with public and private water agencies in South Texas
- Promotes a coordinated and interdisciplinary approach to analyzing specific water related technical, socioeconomic and policy issues

The University of Texas at San Antonio, One UTSA Circle, San Antonio, TX 78249

UTSA The University of Texas at San Antonio™

Research Expertise and Interest

- Water resources development in the Eagle Ford Shale region (*Sharif*)
- Remote sensing precipitation products for Texas (*Sharif and Xie*)
- Physically-based, distributed-parameter runoff modeling and recharge estimation for Texas catchments and aquifers (*Sharif*)
- Flood forecasting and modeling in Texas (*Sharif*)
- Stormwater Management and Control (*Giacomoni & Shipley*)
  - Application of Low Impact Development (LID) and Best Management Practices (BMPs)
- Enhanced membrane treatment of desalination brines (*Johnson and Shipley*)
- Utilizing Plant Root Transport Pathways for Water Desalination and Subsurface Distribution (*Johnson*)
- Water Quality Monitoring (*Shipley, Johnson & Gao*)
- Novel Technologies for Water Treatment and Pollution Control (*Shipley*)
- Comparing and contrasting the success of market-based, acquisition policies (e.g. City of San Antonio's Edwards Aquifer Protection Program), as effective means of protecting quality and quantity of aquifer recharge (*Romero*)

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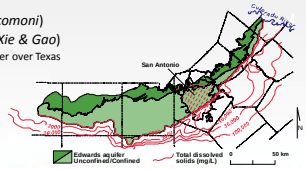
UTSA The University of Texas at San Antonio™

Research Expertise and Interest

- Aquifer Storage and Recovery (*Dutton*)
- Desalination of Edwards Brackish Water (*Dutton & Gao*)
- Water Resources Systems Analysis (*Giacomoni*)
- Effect of aquifer heterogeneity on long-term change of desalination make-up water composition (*Dutton & Gao*)
- Drought Management/ Climate change (*Giacomoni*)
  - Adaptive Demand Management
  - Water Conservation
  - Land/Water Nexus
- Sanitary Sewer Overflows (SSOs) (*Giacomoni*)
- Quantitative Rainfall Measurements (*Xie & Gao*)
  - To better understand the availability of water over Texas



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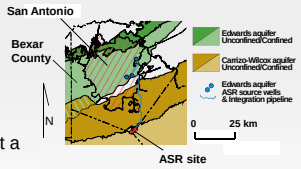
Aquifer Storage and Recovery

(Dutton in collaboration with SAWS)

- Volume of Edwards water in storage in Carrizo aquifer
- Technique for mapping mixing interface between Edwards and Carrizo waters
- Calibration of nuclear magnetic resonance geophysical logs for mapping hydraulic conductivity at a well-field scale
- Monitoring strategy for tracking mixing interface movement



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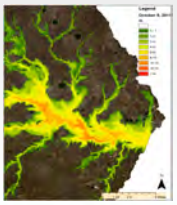
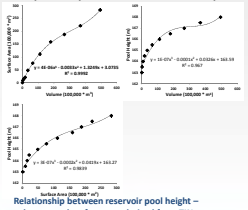
Water resources development in the Eagle Ford Shale region: Crystal City Case Study

(Sharif)

- Study the flood potential near Crystal City and delineate flood plains
- Prepare the hydrologic data for a feasibility study of a dam near Crystal City



Inundation map from October 9, 2011 event



Relationship between reservoir pool height – volume – and surface area derived from TIN

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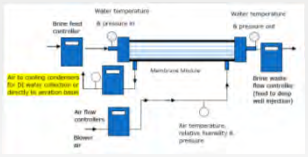
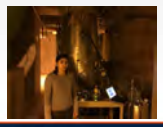
Enhanced membrane treatment of desalination brines

(Johnson and Shipley in collaboration with SAWS)

- focuses on membrane evaporation processes to reduce desalination brine volume
- investigates the potential of coupling membrane evaporation with waste heat generated from activated sludge aeration blower





Work supported by US Bureau of Reclamation

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Water Research at UT Rio Grande Valley

UTRGV

UTB and UTPA

Research at UTB

- Arroyo Colorado Bacterial Source Tracking (2013-2015)
  - TSSWCB grant with five major partners ($350,000)
    - TWRI – Texas Water Resources Institute
    - TIAER – Texas Institute for Applied Environmental Research
    - ACWP – Arroyo Partnership
    - Texas A&M University
    - UTB – University of Texas at Brownsville ($70,000)
      - Local Coordination (presence in the watershed)
      - Collection of in-stream bacterial count samples for enumeration and DNA sequencing
      - Goal: Link E. coli and Enterococcus bacteria water column concentrations to their constituent source
        - » Human, avian, bovine, etc.
        - » Assist in more efficient water quality policy formulation

Research at UTB

- Brownsville Area Resaca Watershed Characterization (just awarded – 2014- 2016)
  - EPA grant with four major partners ($450,000)
    - TWRI – Texas Water Resources Institute
    - TIAER – Texas Institute for Applied Environmental Research
    - ACWP – Arroyo Partnership
    - UTB – University of Texas at Brownsville ($100,000)
      - Local Coordination (presence in the watershed)
      - Water quality data gap analysis and collection of additional data to fill gaps
      - Goal: Characterize watershed boundaries, potential sources of pollution, outreach / community stakeholder input on impairment mitigation measures.

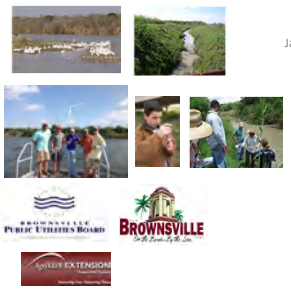
Research at UTB

- EFDC (Environmental Fluid Dynamics Code) Modeling for the Arroyo Colorado (2012-2015)
  - EPA grant with three major partners ($500,000)
    - TWRI – Texas Water Resources Institute
    - TIAER – Texas Institute for Applied Environmental Research
    - ACWP – Arroyo Partnership
    - UTB - University of Texas at Brownsville ($80,000 Share)
      - Education and Outreach
      - Local Coordination (presence in the watershed)
      - Water quality data collection for model calibration and validation

Dr. Frank J. Dirrigl Jr.
LRGV Biomonitoring Laboratory
Environmental & Earth Sciences Program

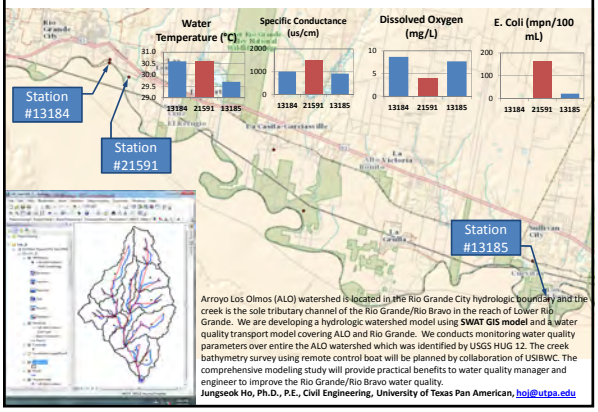
- Stormwater Quality Monitoring
- Irrigation Canal Water Quality Monitoring
- Evaluation of Best Management Practices (BMPs)
- Biomonitoring to Determine Ecosystem Health

Water Quality Sampling in the Arroyo Colorado and Brownsville Area Resacas



Jude A. Benavides, Ph.D.
Jaime Flores, Watershed Coordinator, TWRI
Monica Delgado, B.S. (Env Sci)
Guadalupe Garcia
Rachelle Maldonado
Juan Castaneda
Robert Figueroa-Downing
John Gray, B.S. (Env Sci)

Arroyo Los Olmos Watershed Hydrologic Modeling



Arroyo Los Olmos (ALO) watershed is located in the Rio Grande City hydrologic boundary and the creek is the sole tributary channel of the Rio Grande/Rio Bravo in the reach of Lower Rio Grande. We are developing a hydrologic watershed model using **SWAT GIS model** and a water quality transport model covering ALO and Rio Grande. We conducts monitoring water quality parameters over entire the ALO watershed which was identified by USGS HUG 12. The creek bathymetry survey using remote control boat will be planned by collaboration of USIBWC. The comprehensive modeling study will provide practical benefits to water quality manager and engineer to improve the Rio Grande/Rio Bravo water quality.

Jungseok Ho, Ph.D., P.E., Civil Engineering, University of Texas Pan American, hoj@utpa.edu

UT Tyler Current Water Conservation and Responsible Development Projects

- Key Faculty Involved:
  - Harmonie Hawley (Engineering)
  - Neil Ford (Biology)
  - Lance Williams (Biology)
  - Meryem Saygili (Economics)
  - Josh Banta (Biology)
  - John Placyk (Biology)
  - Thomas Guderjan (Anthropology)

- Key Project Areas:
  - The effects of water use and manipulation on endangered species.
  - Waterway interruption (bridge construction) effects on native aquatic organisms.
  - Hydrologic and hydraulic modeling of surface water in particular to estimate flow and stress effects on threatened habits.
  - Method development to determine the specific surface area of solid media. The main interest is to understand contaminant movement in groundwater and improved water remediation.
  - Geotechnical engineering advice, research, analysis and development support for oil and gas offshore development projects, which support offshore structures and pipelines.

Project Spotlight: Big Thicket (Dr. Neil Ford, UT Tyler Biology)

Texas has over fifty species of unionid mussels in multiple river basins that often have isolated drainage into the Gulf of Mexico. The species composition in southeastern Texas differs significantly from that of central and western areas. Southeast Texas is also a region where the construction of reservoirs and smaller impoundments has been prevalent. The change in water flow downstream of dams has major impacts on mussel diversity and abundance. In addition, erosion from agricultural land, water pollution and commercial harvesting have likely been impacting the freshwater mussels of this area. However, the Neches and its tributaries above Beaumont receive some environmental protection from the lands of the Big Thicket National Preserve. Whether this has reduced the factors causing mussel declines elsewhere is unknown since mussel surveys in the area are very limited.

Specific Goals of the Project: Survey for mussels in larger streams and rivers of 4 units of the Big Thicket Nature Preserve with emphasis given to areas where habitat characteristics are appropriate for mussels.

Water Research at UT Austin

TEXAS
The University of Texas at Austin

Center for Research in Water Resources

The University of Texas at Austin
J.J. Pickle Research Center

The mission of CRWR is to:

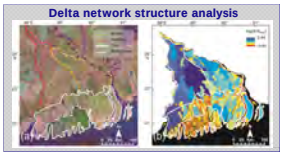
- serve as the central focus for environmental and water resources research at the University;
- communicate the results of its advanced research to government, industry, and other educational institutions;
- work with other agencies and institutions in Texas to solve the State's complex water problems:
- act as a regional center for water-related research, education, planning, and practical design;
- share relevant experience and provide support to graduate students of the University by involving them in applied research.

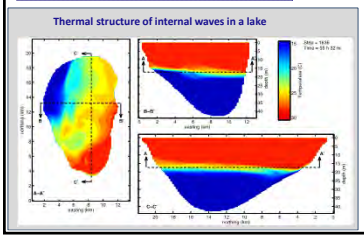
CRWR Researchers, Staff and Students

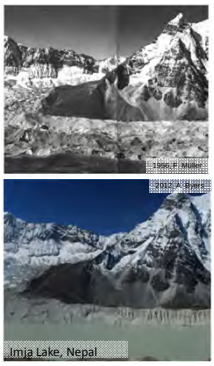
Long standing strengths in Water Treatment and Management

- 15 faculty
  - Plus 4 affiliates in the Jackson School of Geosciences
- 3 research scientists
- 9 research fellows (e.g., post-docs, research associates, etc.)
- ~80 graduate students
- 3.5 administrative staff
- 0.25 professional staff
- Average research funding of $4-5 million/yr

Regional Water Modeling



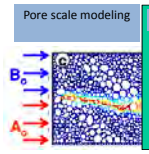




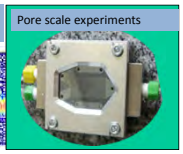
Reactive Transport in Porous Media

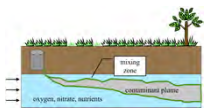
Applications to hazardous waste remediation & geological carbon sequestration

Pore scale modeling



Pore scale experiments





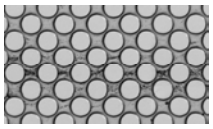
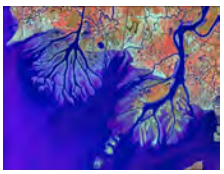


Image analysis of biomass growth and precipitation in model aquifers

Coastal Restoration

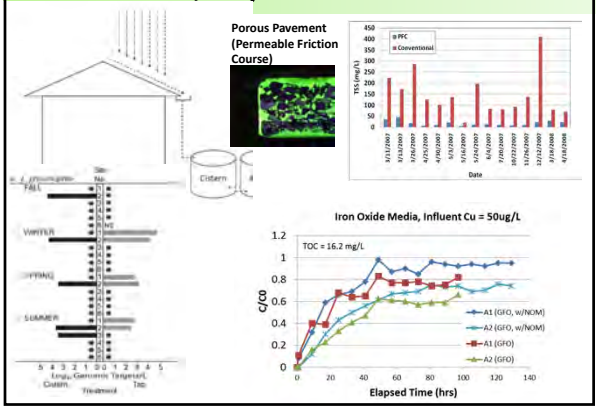


NSF-funded Delta Dynamics Collaboratory:

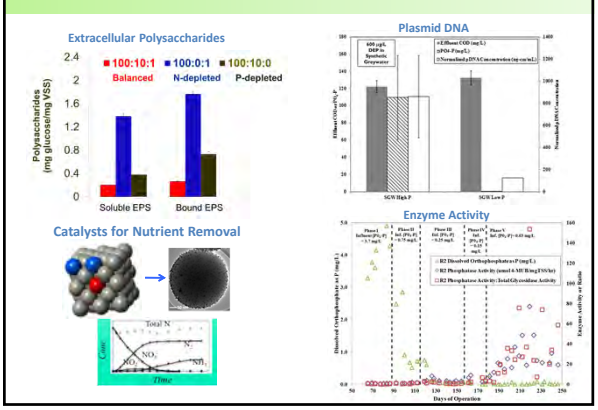
Field observatory and numerical modeling brings together five different disciplines in a multidisciplinary effort to recapture land mass

From Natural to Engineered Systems

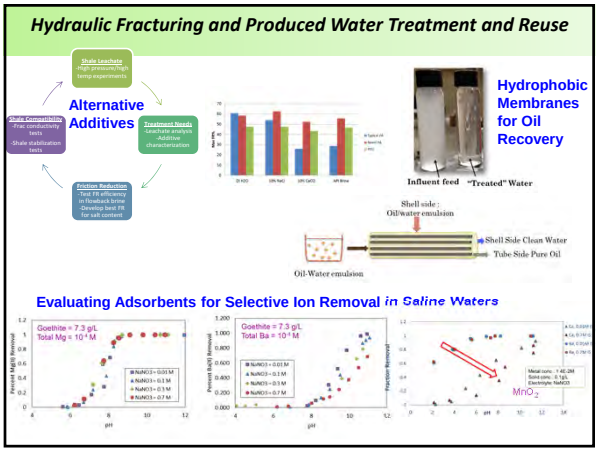
Rainwater, Greywater and Stormwater



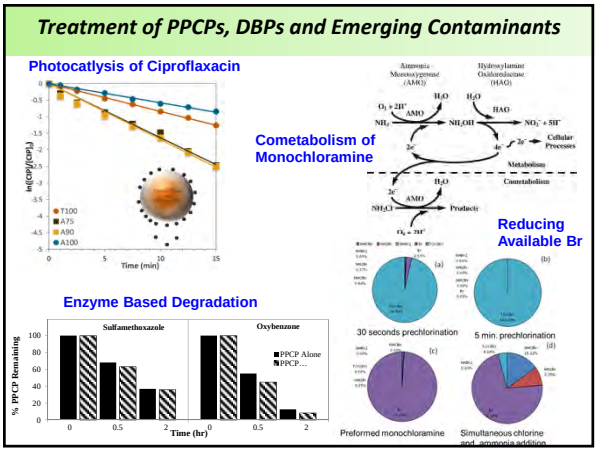
Nutrients in Wastewaters



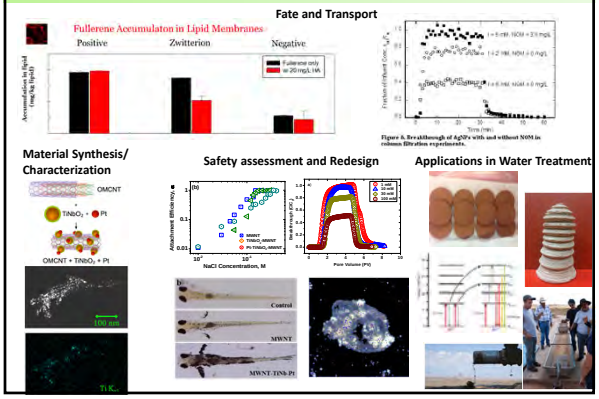
Hydraulic Fracturing and Produced Water Treatment and Reuse



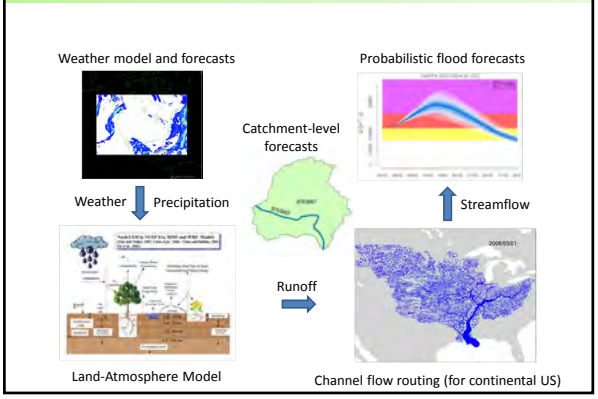
Treatment of PPCPs, DBPs and Emerging Contaminants



Nanoparticles



Flooding and Drought



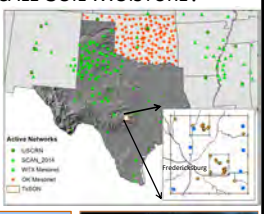
Texas Soil Observation Network (TxSON)

How can we utilize large-scale Soil Moisture?

NASA SMAP Core Cal/Val Site:

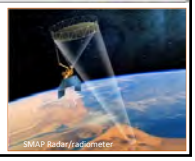
- Nested design: 41 total stations
- Covering 500 square miles, eastern Gillespie County
- Soil moisture at 5, 10, 20 and 50 cm
- Real-time data collection
- Ground validation for SMAP/NLDAS

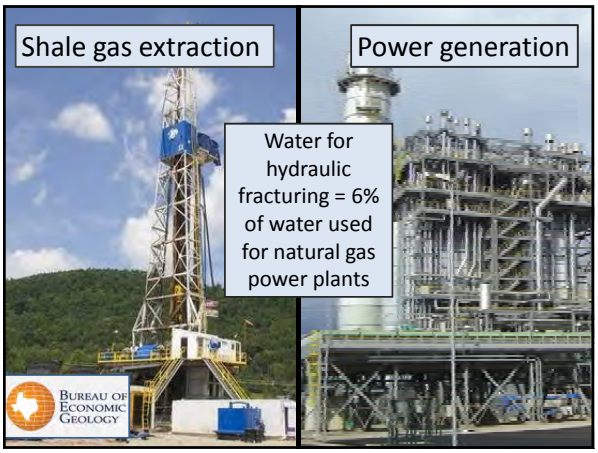
http://www.beg.utexas.edu/txson/



NASA Soil Moisture Active/Passive (SMAP)

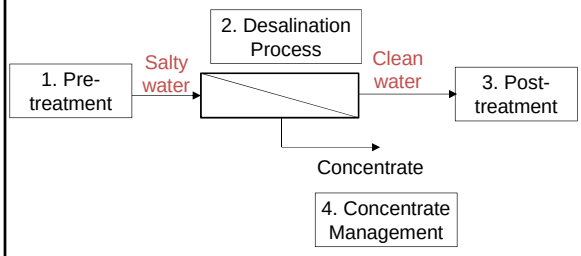
- Launched January 31, 2015
- Global soil moisture at 9km
- ~every 50 hours





Research Focused on Desalination

Four key areas



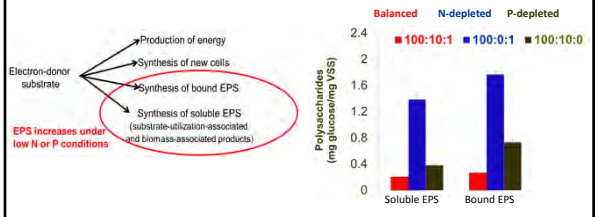
1. Pretreatment requirements, challenges, and opportunities

- Bio-fouling control (disinfection) often uses:
  - Chlorine—dechlorination or chlorine resistant membranes would be required
  - Ozone—formation of bromate in bromide-containing waters
  - UV
- Particle removal
  - Conventional treatment: coagulation & filtration
  - Membrane treatment: ultrafiltration
- Scaling control
  - Acid addition—prevents oxide, hydroxide, and carbonate solids from being formed, but adds to TDS
  - Organic anti-scalants
  - Silica control—precipitation prior to first stage or interstage treatment

1. Pre-Treatment Example: Reduction of biofouling

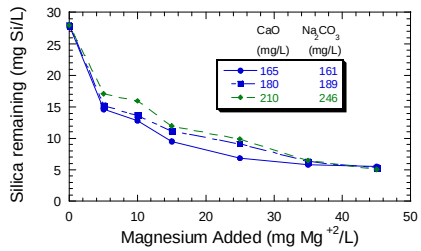
Lead Investigator: M. Kirisits

- Production of extracellular polymeric substances (EPS) can lead to biofouling of granular media and membrane filters.
- What operating conditions minimize EPS production?



1. Pretreatment Example: Precipitation can be used to reduce silica, calcium, barium

- Addition of magnesium increased silica removal via precipitation



Initial Amounts Added:

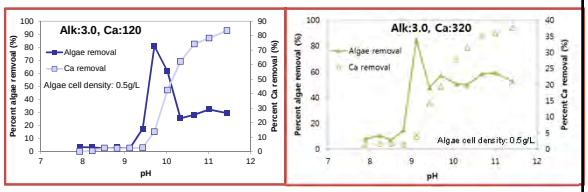
Ca^{+2}	50 mg/L
Mg^{+2}	20 mg/L
Si	28 mg/L

Lead Investigators: D. Lawler

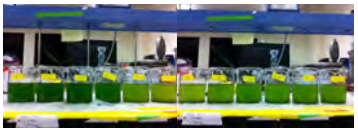
1. Pretreatment Example : Removal of algae and Ca via coagulation/flocculation

Lead Investigators: L. Katz and K. Kinney

- Maximum removal of algae coincides with the onset of Ca precipitation.



Algae cell density: 0.5g/L,
Alk: 1.0meq/L, Ca: 120mg/L



2. Desalination Membrane Processes

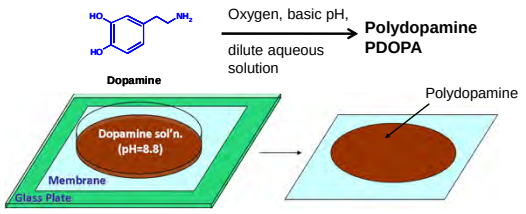
- Chlorine-tolerant desalination membranes based on sulfonated polymers.
- Fouling resistant ultrafiltration and microfiltration membranes.
- Desalination membranes by melt processing.

- Fundamentals of fouling of porous membranes.
- Fundamentals of water and ion transport in polymers.
- Influence of multiphase block copolymer morphology on water and ion transport.

2. Membrane Development: Fouling resistant membrane coatings

Lead Investigator: B. Freeman

- Polydopamine deposits onto and adheres to virtually any membrane surface and renders that surface hydrophilic.



B.D. McCloskey, H.B. Park, H. Ju, B.W. Rowe, D.J. Miller, B.J. Chun, K. Kin, B.D. Freeman, *Polymer* 51, 2010, 3472-3485; D.R. Dreyer, D.J. Miller, B.D. Freeman, D.R. Paul, C.W. Bielawski, *Langmuir* 28, 2012, 6428-6435.

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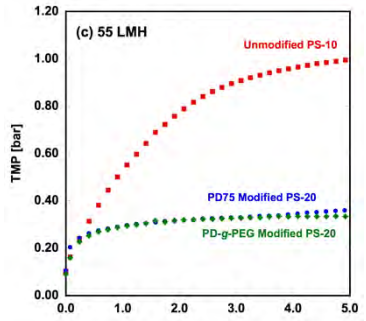
2. Surface Modified Membranes Outperform Unmodified Membranes



Lead Investigator: B. Freeman

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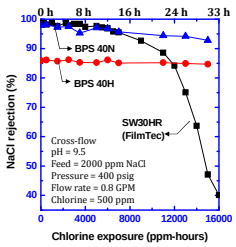
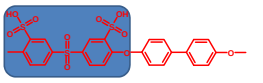
2. Membrane Development: Chlorine Tolerant Membranes

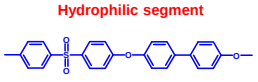
Lead Investigator: B. Freeman

- **Sulfonated polysulfone membranes exhibit high chlorine tolerance**





Hydrophilic segment



Hydrophobic segment

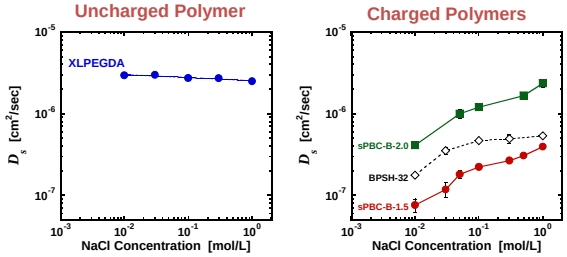
- **High water permeability**
- **High chlorine tolerance**
- **Excellent fouling-resistance**
- **Good reproducibility**

H.B. Park, B.D. Freeman, Z.B. Zhang, M. Sankir, and J.E. McGrath, Highly Chlorine-Tolerant Polymers for Desalination, *Angew. Chem.-Int. Edit.* 47 6019-6024 (2008).

2. Membrane Treatment: Understanding Mechanisms

Lead Investigator: B. Freeman

- Influence of Salt Concentration on Salt Diffusion Coefficient Depends on Polymer Charge



Geise, G.M., B.D. Freeman, and D.R. Paul, "Sodium Chloride Diffusion in Sulfonated Polymers for Membrane Applications," *J. Membrane Sci.*, 427, 186-196 (2013).

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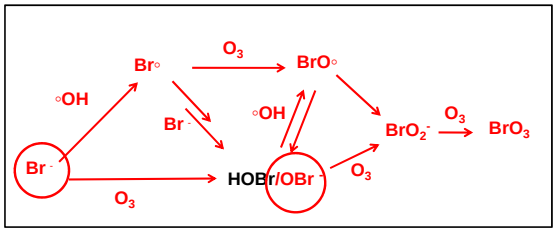
3. Post-desalination water treatment: challenges and opportunities

- Water may be too clean to use or too corrosive to pipe
  - Adding minerals for taste (Ca, Mg)
  - Adding carbonate to adjust alkalinity
  - Possible to blend with small volume of concentrate, but water quality essential
  - Possible stripping of H_2S
  - Adding polyphosphates for corrosion control
- Disinfection; Treatment of disinfectant residuals

Disinfection By-Products: Bromate formation



Pinkernell and von Gunten, (2001)

- Desalinated seawater can contain elevated bromide.
  - 650 µg/L (Magara et al., 1996; Obolensky and Singer, 2005)
- Bromate (BrO_3^-) is formed from bromide (Br^-) during ozonation.

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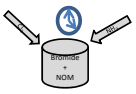
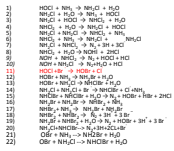
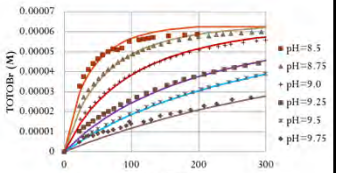
Manipulating operating conditions in pre-chloramination to decrease free bromide

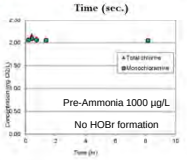
Lead Investigators: G. Speitel and L. Katz

Unified Haloamine Model can guide operating strategies that tie up bromide in other non-reactive species









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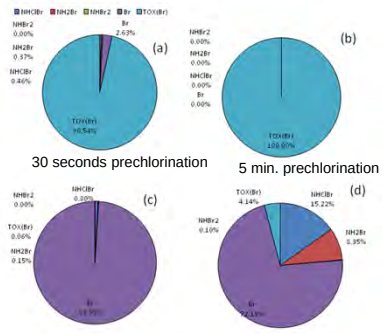
Engineering significance of pre-chloramination

- Sequestration of bromide is a key to controlling bromate formation.
- Less bromate will be formed with less free bromide ion available.



30 seconds prechlorination

5 min. prechlorination

Preformed monochloramine

Simultaneous chlorine and ammonia addition

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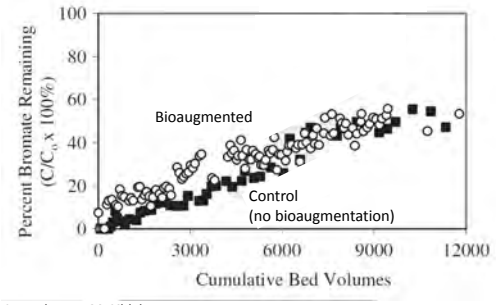
Lead Investigator: G. Speitel and L. Katz

Post-Treatment: Biological bromate reduction

Lead Investigator: M. Kirisits

- Microbial reduction of BrO_3^- to Br^-
  - Occurs under low dissolved oxygen conditions
- Bioaugmentation of isolated bromate-reducing bacteria to a granular activated carbon filter was studied.

Bioaugmentation appears unnecessary. Indigenous bacteria reduce bromate.



Lead Investigator: M. Kirisits

4. Concentrate Management

- For inland desalination, concentrate disposal is the predominant challenge
- Reverse osmosis (RO) recovery is limited
- Increasing recovery means decreasing concentrate volume
- Consider a treatment of concentrate to increase recovery

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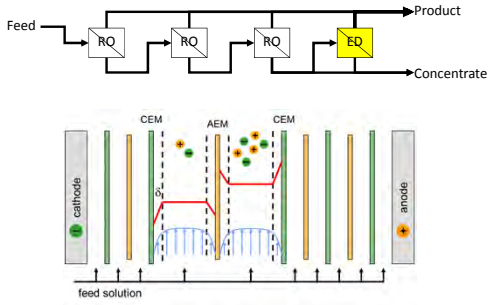
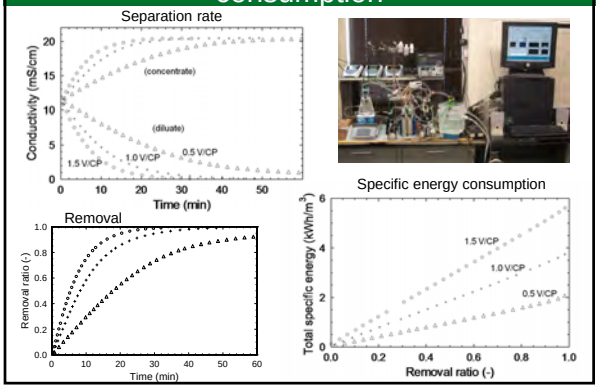
Concentrate Management: Electrodialysis treatment

Lead Investigator: D. Lawler



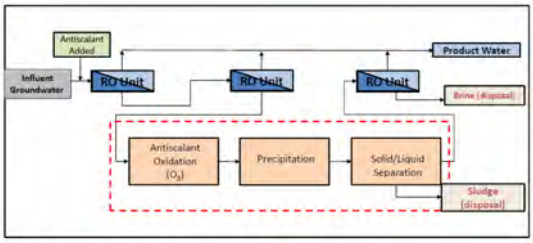
Strathmann, H. (2004). *Ion-exchange membrane separation processes*, Elsevier, Boston.
AWWA. (1995). "M38 - Electrodialysis and Electrodialysis Reversal." P. Murray, ed.

Electrodialysis: Performance and energy consumption



Concentrate Management:RO concentrate treatment

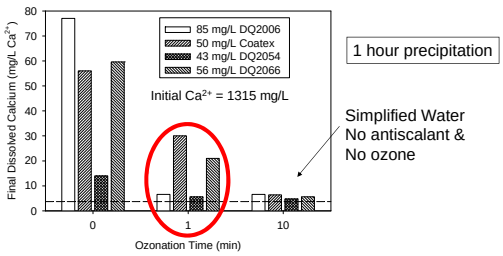
Lead Investigators: Des Lawler and Benny Freeman



Minimizing Concentrate through chemistry
Advanced Oxidation to remove antiscalant
Increase pH, add carbonate to precipitate calcium carbonate

Effects of antiscalant and antiscalant ozonation on calcium precipitation

- Ozonation of antiscalant can allow for enhanced precipitation of calcium during concentrate treatment.



Experimental conditions: Ozonation 3 mg/min O_3 at pH 6.0, H_2O_2/O_3 = 0.8, precipitation 1 hr at pH 10.5, $NaHCO_3$ and NaOH added for precipitation.

Lead Investigators: D. Lawler and Benny Freeman

Texas State University System Water Overview

Dr. Andrew Sansom
Executive Director

Presentation to Texas Water Development Board

The Meadows Center for Water and the Environment
Texas State University

SUL ROSS STATE UNIVERSITY

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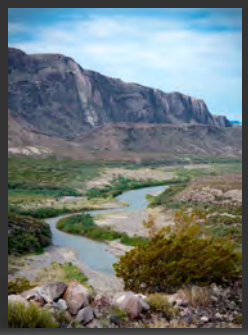
Rio Grande Research Center



- Create a basin-wide perspective for the sustainable use of water resources within the bi-national Rio Grande watershed.
- Conduct sustainable agricultural water conservation.
- Foster intergovernmental, academic and stakeholder collaboration.
- Conduct outreach and education about the sustainable use of natural resources.

The Meadows Center for Water and the Environment

Sustainable Agricultural Water Conservation

- Collaboration with
  - Lamar University
  - Sam Houston State University
  - Texas State University
  - National Park Service
  - Texas Agrilife
  - Texas A&M
  - New Mexico State University
  - Texas Parks & Wildlife
  - UT-Pan American
  - Rocky Mountain Bird Observatory
  - Utah State University Trans-Pecos Water Trust
  - Brewster County Ground Water District

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Sustainable Agricultural Water Conservation

- Identification and analysis of alternative technologies and methodologies for increasing water use efficiency in agricultural irrigation practices.

The Meadows Center for Water and the Environment

Deployable Aerobic Aqueous Bioreactor

- Wastewater treatment system with high efficiency in a small, modular unit designed to fit within a 20x40 cargo container for transport and use anywhere.
- Collaboration between
  - Texas Institute for Environmental Studies at Sam Houston State
  - Sul Ross State University Department of Biology
  - Lamar University Department of Civil Engineering
  - Army Corps of Engineers Engineer Research and Development Command

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Sam Houston State University

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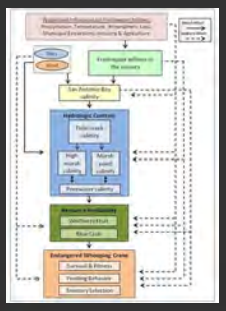
Aquatic Ecosystems Ecology Lab



- Research to apply a broad, holistic ecosystem approach to understanding how hydrologic connectivity and other environmental drivers (both natural and anthropogenic) work to impact coastal marsh processes at varying spatial and temporal scales

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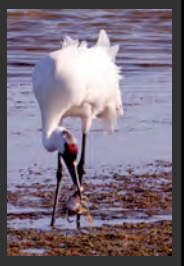
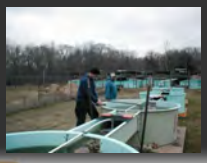
Ecosystems, Species, and Wastewater Treatment

- Development of a portable wastewater treatment unit
- Research on ecosystem dynamics around Aransas Bay caused by drought and anthropomorphic changes that affect the endangered whooping crane.





- Research on invasive fish species in West Texas and the Red River.

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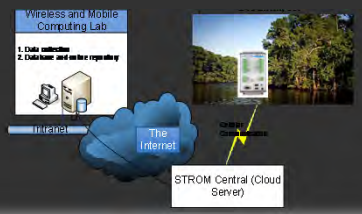
LAMAR UNIVERSITY

The Meadows Center for Water and the Environment

Wireless Sensor Network for Measurement, Modeling, and Prediction in Water Resource Management.

- Accomplish a potentially transformative change in water resource management through application of state-of-the-art Wireless Sensor Networks technology.
- Apply real-time and large-scale water quantity and quality data to characterize interactions among water resources, climate changes, and human impacts, thus providing more accurate prediction for water resource management under different climate scenarios.



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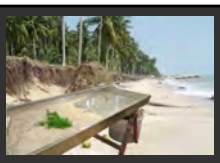
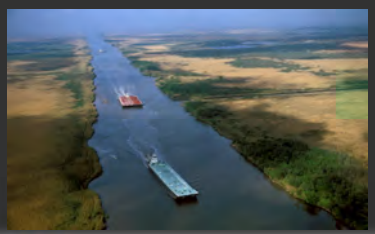
- Investigate Fluid-Hydraulic Structure Interactions and Gulf Highway 87 Shoreline Protections using a tool that simulates river and other geologic processes with remarkable accuracy.





- Provide scientific assessment and technical knowledge for solving wake wash issues, such as its impact on moored ships, coastline erosion, and dike safety.

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- Process Evaluation of Biogas Production for Sustainable Waste Management in Refineries and Paper Industries
- Impact of Global Climate Change on the Precipitation and Acid Deposition in the Rio Grande River Basin Region

- Development & Optimization of Decentralized Wastewater Treatment Systems for Forward Military Operations

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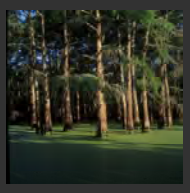

'Nutrient transport and water quality monitoring in the Sabine Lake Bayous'

by Xing Fang (Department of Civil Engineering, College of Engineering, Lamar University), Texas Water Development Board contracted report number 2000483322 (2000).

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TEXAS STATE UNIVERSITY®

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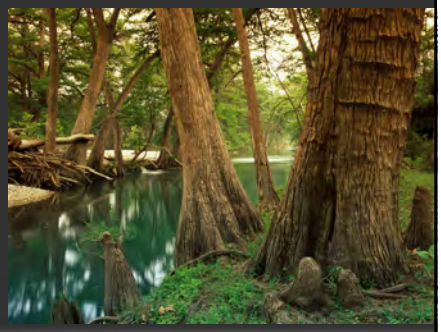
Research

Environmental Flows

Groundwater

Watershed Protection and Management

Conservation



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Underwater Archaeological and Scientific Exploration

Monterrey Ship Wreck - Cannon

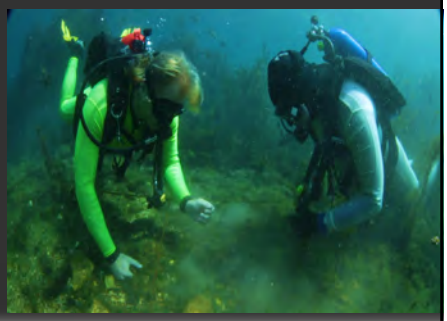
The Meadows Center for Water and the Environment

Stewardship

Spring Lake Restoration

Endangered Species

Cultural Resources



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Service and Conservation

Texas Stream Team

Environmental Policy

Negotiation and Mediation

The Meadows Center for Water and the Environment

Education

125,000 Visitors Annually

Conferences

Two Major Book Series

Conservation Leadership

The Meadows Center for Water and the Environment

High-Tech Experiential Education

Prototype Technology Integration and Use

- Technology integration test bed
- Accommodate :
  - 17,500 K-12 students in class groups
  - 125,000 children and adults unguided

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High-Tech Experiential Education

- **iPad – iPhone for outdoor aquatic science instruction**
  - **Species ID Key**
  - **GPS Photo Scavenger Hunt**
  - **Journaling**
  - **Social-Network Ready**
  - **Games**
  - **Teacher-Friendly,**
  - **QR Code Scanner**
  - **Documents,**
  - **Videos**
  - **Photos**
  - **Links**

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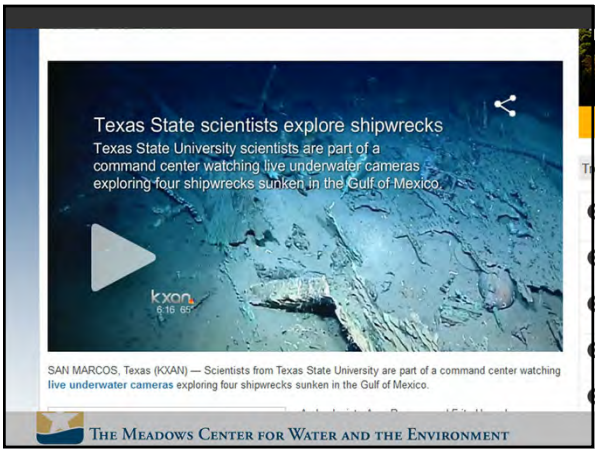

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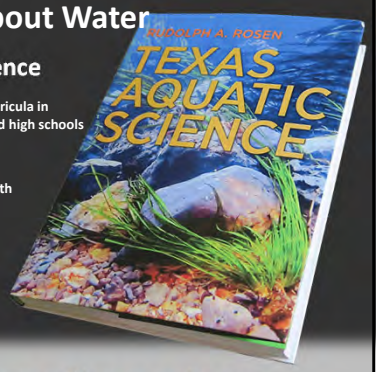
Effective Pathway for Teaching about Water

Texas Aquatic Science

- Texas' first comprehensive curricula in Aquatic Science for middle and high schools students
- Meets all state standards for education and concurrence with TEKS
- Most extensive curricula of its kind in the nation
- Invited review by all Tx Science Teachers as developed



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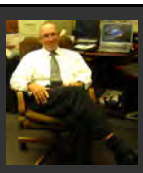
Dr. Thom Hardy's Recent TWDB Projects



- Publication with A&M Press of *Texas Riparian Areas*, 2011-2012: $38,500
- Environmental Flows, Colorado/Lavaca Rivers -Freshwater from the Colorado River to East Matagorda Bay Project (An Evaluation of the Use of Siphons or Pipelines to Deliver Local Inflows to East Matagorda Bay), 2014-2105: $62,500
- Evaluation of the Use of Channel Cross-Section Data to Estimate Instream Flow Requirements (Creation of a database of historic rivers cross sectional data from Texas river systems database suitable to allow development of a classification scheme), 2010-2014: $36,000

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Meredith Miller Senior Program Coordinator

- Design, Permitting and Installation of Subdivision-Scale Rainwater Harvesting Systems as a Water Supply Strategy for the Texas Hill Country, 2011-2013: $73,710 (with an additional $33,000 match)

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