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Managing Water in the West

Guidance for the Evaluation of Produced Water as an Alternative Water Supply

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AWWA Sustainable Water Management Conference

Katharine Dahm
Katie Guerra

U.S. Department of the Interior
Bureau of Reclamation

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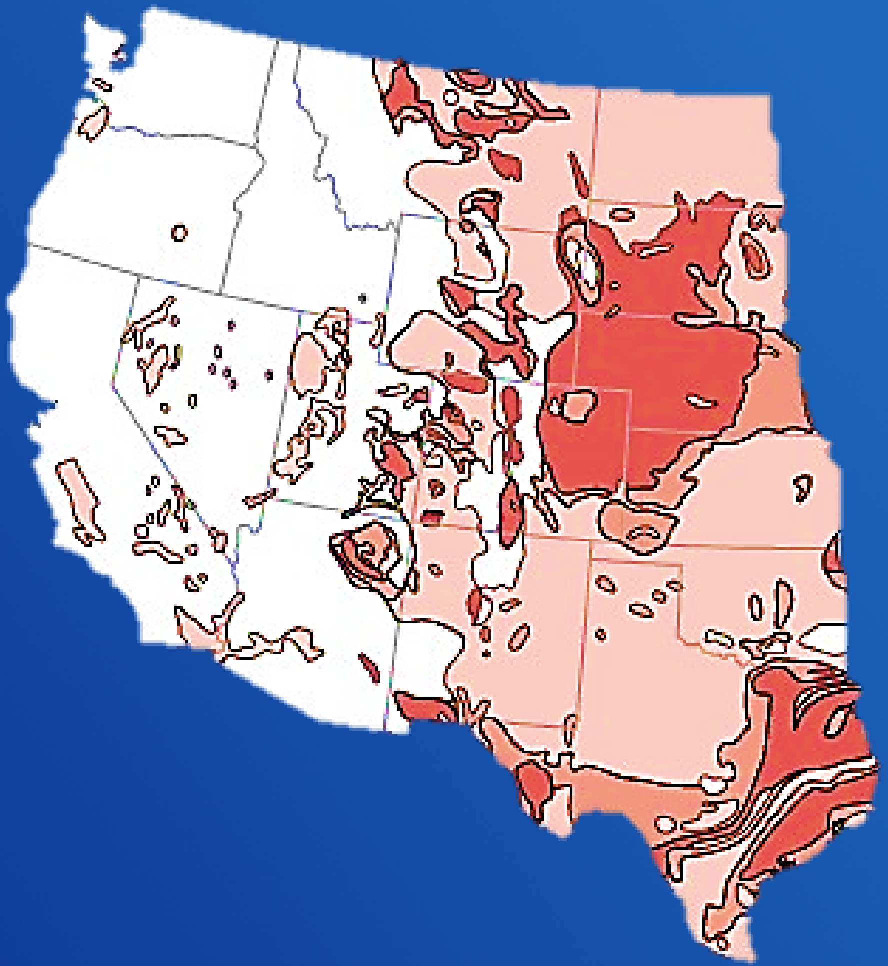
- Identify potential “new water” sources:
  - brackish surface and groundwater
  - reclaimed wastewater
  - produced water
  - seawater
- Identify location, quantity, quality, and accessibility of water supply and demand
- Determine risk of water shortages and potential conflict



Saline Groundwater Resources USGS, W. Alley (2003) from Feth et al. (1965)

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Produced Water Resources in the western United States

- Over 80% of oil and gas production occurs in the western US
- O&G industry water generation and water demand:
- National produced water volumes > 2 billion gal/day
- Hydraulic fracturing uses 500,000 gal to >10,000,000 gal of water per fracturing

API (2012), US Gas Shale Plays

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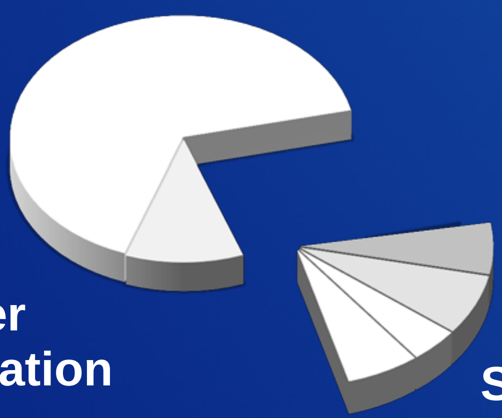
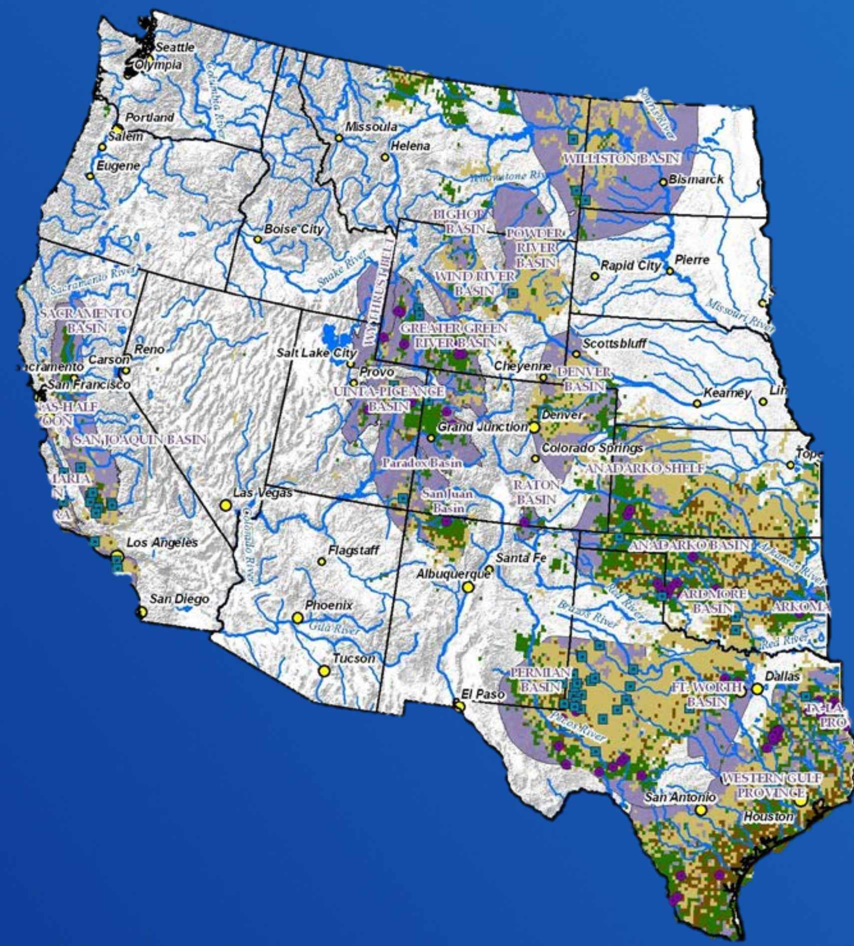
Where do we fit into produced water?

Western Water Portfolio





Reclamation (2011), Conventional Oil and Gas

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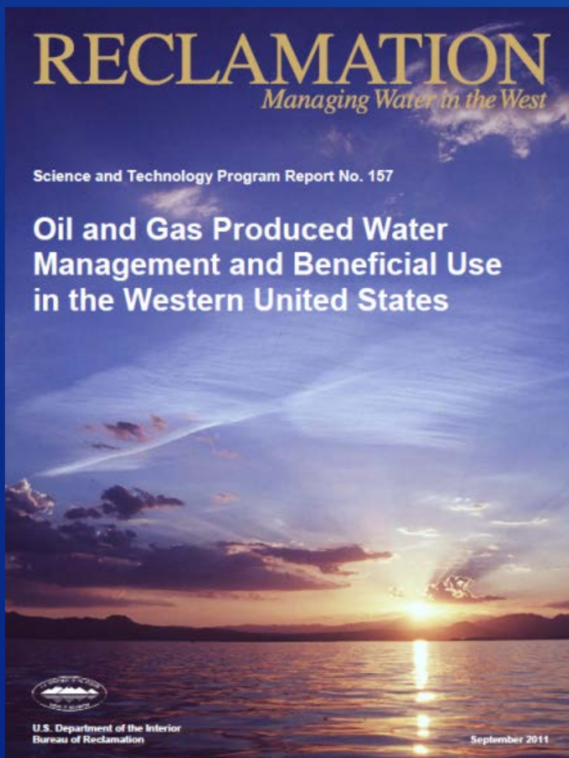
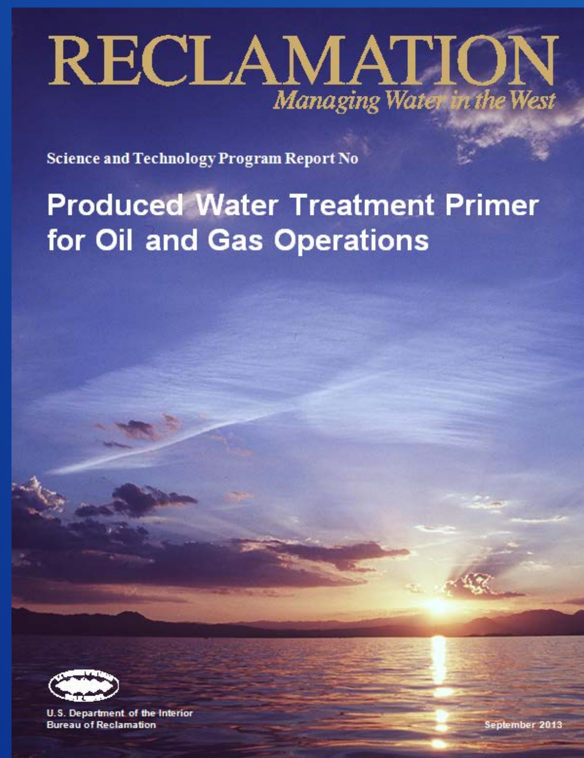
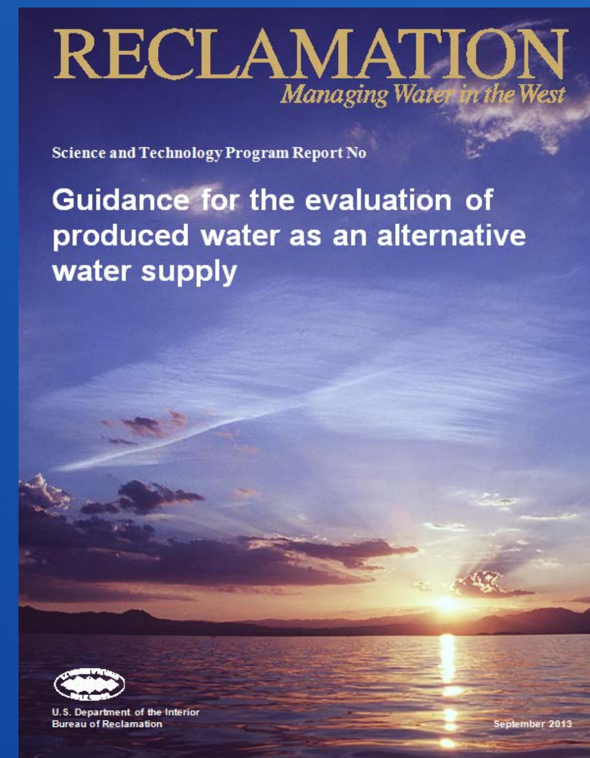
Reclamation Produced Water Management Reports







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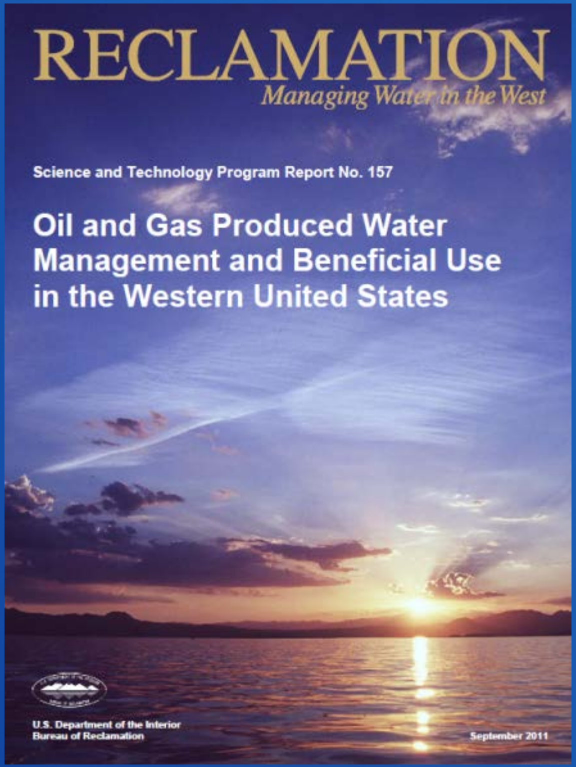
Reclamation Produced Water Management Reports

I. Beneficial Use Opportunities
   - Production Locations
   - Water Quality Requirements
   - GIS Based Examples

II. Produced water characterization
   - Produced Water Volumes
   - Produced Water Quality

III. Water treatment technologies
   - Technology Assessments
   - Technology Comparison



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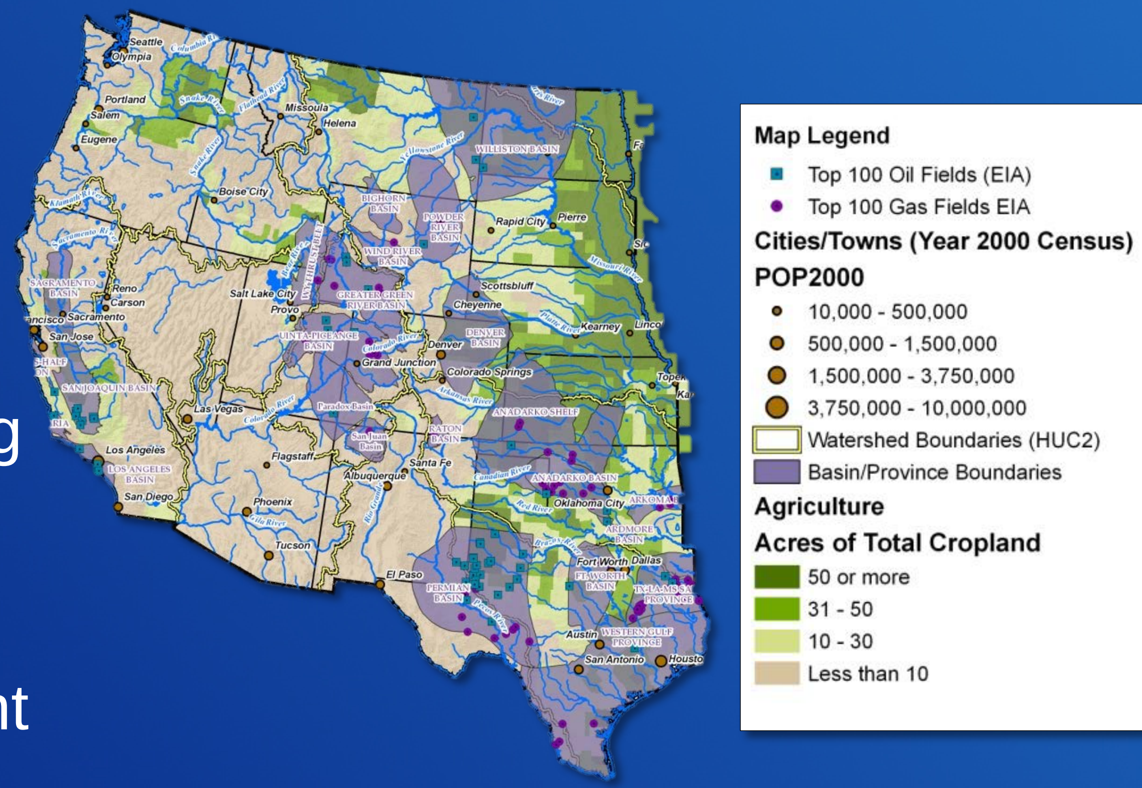
Beneficial Use Opportunities in the western US

- Irrigation
- Livestock watering
- Stream flow augmentation
- Hydraulic fracturing
- De-icing fluids
- Industrial uses
- Emergency drought supplies



Reclamation (2011), Agricultural areas overlaid with O&G basins

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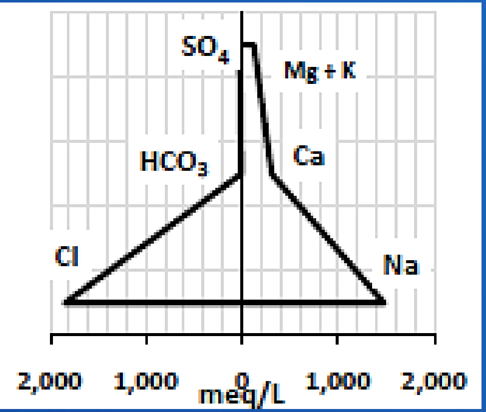
Produced Water Characterization

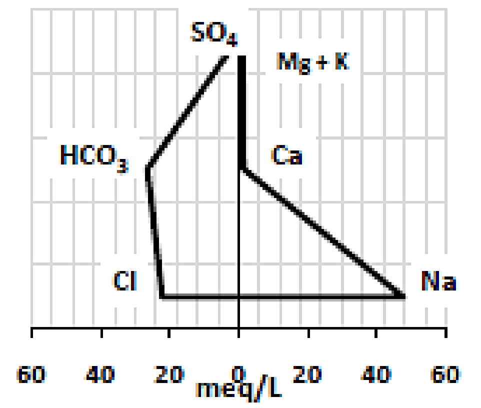
Table 13. Common inorganic constituents in conventional produced water

Constituent	Units	Low	High	Reference
TDS	mg/L	100	400,000	USGS produced water database
Sodium	mg/L	0	150,000	USGS produced water database
Chloride	mg/L	0	250,000	USGS produced water database
Barium	mg/L	0	850	Fillo 1992
Strontium	mg/L	0	6,250	Fillo 1992
Sulfate	mg/L	0	15,000	USGS produced water database
Bicarbonate	mg/L	0	15,000	USGS produced water database
Calcium	mg/L	0	74,000	USGS produced water database

Conventional Oil and Gas



Coalbed Natural Gas



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Water Treatment Technologies

- Pretreatment Technologies
  - Bioreactors and Membranes
  - Filtration and Floatation
  - Adsorption and Oxidation
- Desalination Technologies
  - Membrane Filtration
  - Thermal Processes
  - Electrodialysis
- Commercial Process Combinations
  - Veolia OPUS™
  - Higgins Loop™

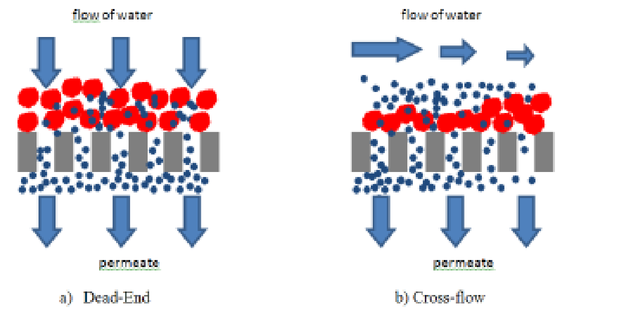

Figure 23. Dead-end versus cross flow filtration.

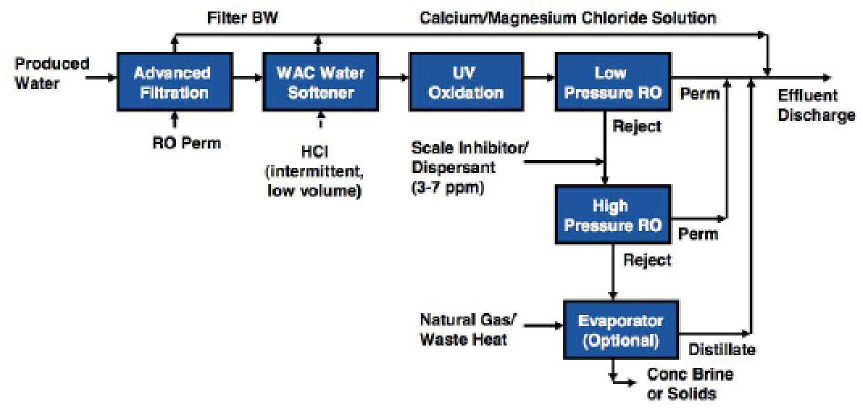

Figure 24. Schematic diagram of CDM produced water treatment process.

Reclamation (2011), Produced Water Treatment Technology Schematics

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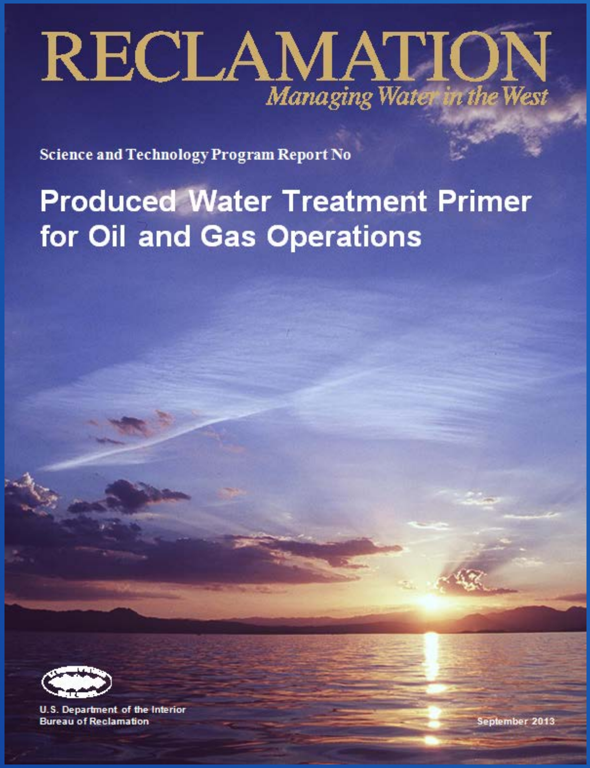
Reclamation Produced Water Management Reports

I. Categorizing water treatment capabilities and performance
   - Describe technologies based on classification of mechanism

II. Technologies and applications
   - Development and implementation of water treatment technologies

III. Catalog of technologies
   - Provide operational experience and performance data when available



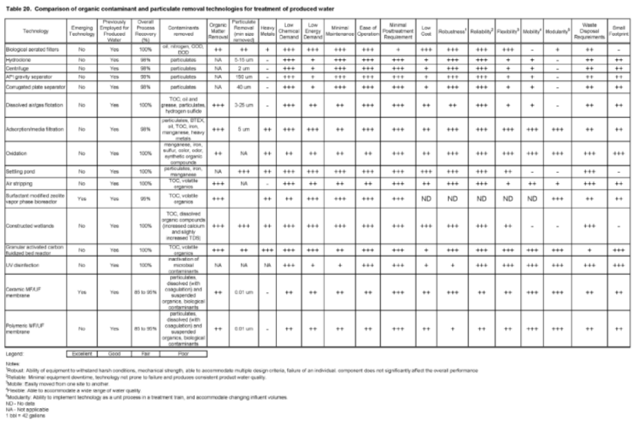
Categorizing Water Treatment Capabilities and Performance

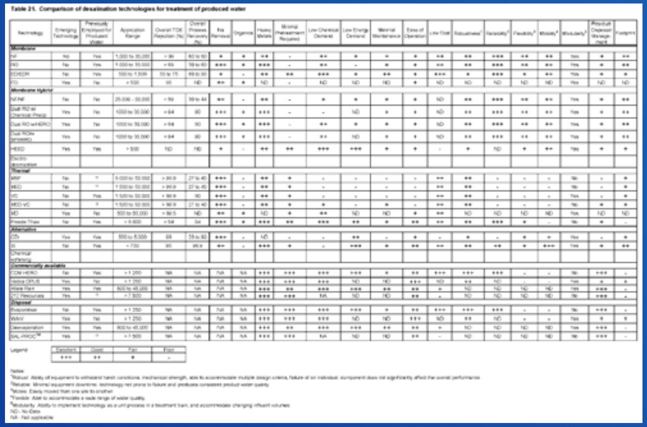
Reclamation (2011), Technology Capabilities

Technology	Emerging Technology	Previously Employed for Produced Water	Application Range	Overall TDS Rejection (%)	Overall Process Recovery (%)
Membrane					
NF	No	Yes	1,000 to 35,000	> 99	60 to 80
RO	No	Yes	1,000 to 35,000	> 99	30 to 60
ED/EDR	No	Yes	500 to 1,500	55 to 75	80 to 90

Technology	Robustness[1]	Reliability[2]	Flexibility[3]	Mobility[4]	Modularity[5]	Residual Disposal/Manage-ment
Membrane						
NF	++	+++	++	++	Yes	+
RO	++	+++	++	++	Yes	+
ED/EDR	+	+++	+	++	Yes	+

Excellent	Good	Fair	Poor
+++	++	+	-





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Development and Implementation of Water Treatment Technologies

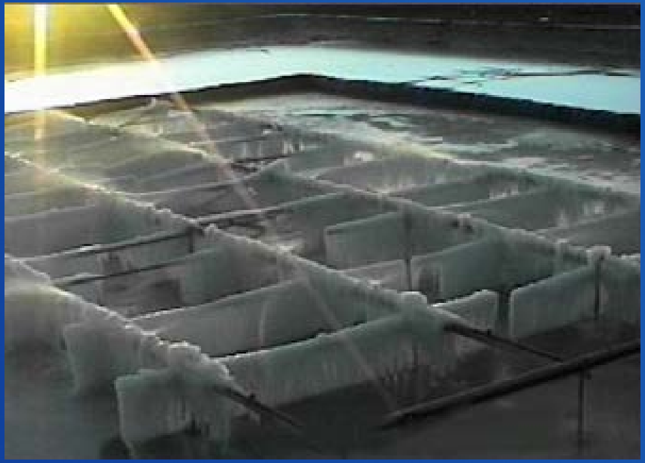
Water Treatment

Common Challenges
Variable water quality and quantity
Removal of trace metals
Minimize energy consumption
Reduce chemical consumption
Decrease concentrate/residuals
Robust system designs
Cost effective water treatment
Flexible, mobile, modular systems

Energy Industry

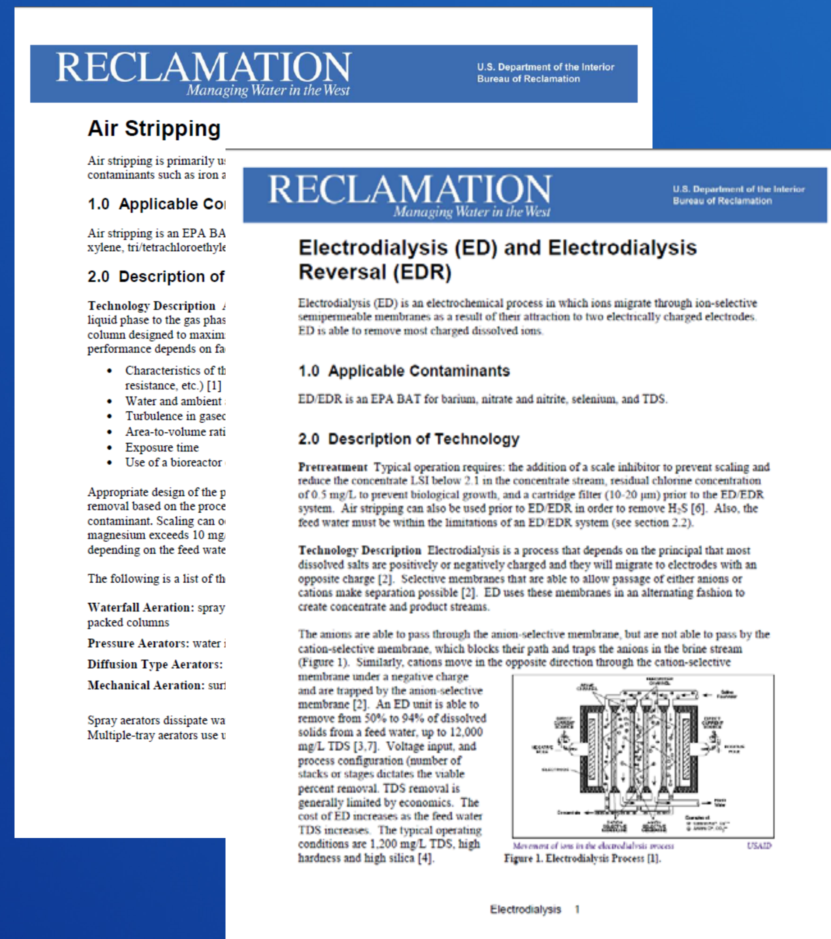
Reclamation Funding of Produced Water Treatment Technologies

- R&D efforts with commercialized technologies used in O&G
  - Altela Rain™ (Upper picture)
  - Freeze-thaw (Lower picture)
- Research areas of interest to O&G
  - Concentrate management
  - Zero liquid discharge
  - Mineral recovery
  - Membrane distillation
  - Forward osmosis



Catalog of Commercial Treatment Technologies

- Categorical technology classification
- Applicable contaminants removed
- Description of technology
- Example treatment train
- Examples of commercial technology manufactures
  - Technology surveys
  - Pilot and full scale applications of technology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Air Stripping

Air stripping is primarily u
contaminants such as iron a

1.0 Applicable Co

Air stripping is an EPA BA
xylene, tri/tetrachloroethyle

2.0 Description of

Technology Description A
liquid phase to the gas phas
column designed to maxim
performance depends on fa

- Characteristics of th resistance, etc.) [1]
- Water and ambient
- Turbulence in gaseo
- Area-to-volume rati
- Exposure time
- Use of a bioreactor

Appropriate design of the p
removal based on the proce
contaminant. Scaling can o
magnesium exceeds 10 mg
depending on the feed wate

The following is a list of th

Waterfall Aeration: spray
packed columns

Pressure Aerators: water i

Diffusion Type Aerators:

Mechanical Aeration: surf

Spray aerators dissipate wa
Multiple-tray aerators use u

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Electrodialysis (ED) and Electrodialysis Reversal (EDR)

Electrodialysis (ED) is an electrochemical process in which ions migrate through ion-selective semipermeable membranes as a result of their attraction to two electrically charged electrodes. ED is able to remove most charged dissolved ions.

1.0 Applicable Contaminants

ED/EDR is an EPA BAT for barium, nitrate and nitrite, selenium, and TDS.

2.0 Description of Technology

Pretreatment Typical operation requires: the addition of a scale inhibitor to prevent scaling and reduce the concentrate LSI below 2.1 in the concentrate stream, residual chlorine concentration of 0.5 mg/L to prevent biological growth, and a cartridge filter (10-20 µm) prior to the ED/EDR system. Air stripping can also be used prior to ED/EDR in order to remove H_2S [6]. Also, the feed water must be within the limitations of an ED/EDR system (see section 2.2).

Technology Description Electrodialysis is a process that depends on the principal that most dissolved salts are positively or negatively charged and they will migrate to electrodes with an opposite charge [2]. Selective membranes that are able to allow passage of either anions or cations make separation possible [2]. ED uses these membranes in an alternating fashion to create concentrate and product streams.

The anions are able to pass through the anion-selective membrane, but are not able to pass by the cation-selective membrane, which blocks their path and traps the anions in the brine stream (Figure 1). Similarly, cations move in the opposite direction through the cation-selective membrane under a negative charge and are trapped by the anion-selective membrane [2]. An ED unit is able to remove from 50% to 94% of dissolved solids from a feed water, up to 12,000 mg/L TDS [3,7]. Voltage input, and process configuration (number of stacks or stages dictates the viable percent removal. TDS removal is generally limited by economics. The cost of ED increases as the feed water TDS increases. The typical operating conditions are 1,200 mg/L TDS, high hardness and high silica [4].

Movement of ions in the electrodialysis process USAID

Figure 1. Electrodialysis Process [1].

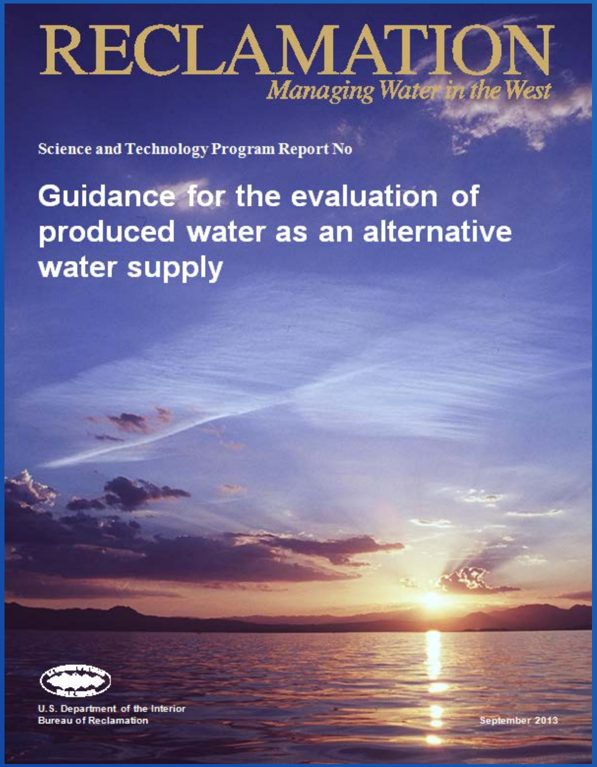
Electrodialysis 1

Reclamation Produced Water Management Reports

I. Locations of opportunity
   - Regional GIS Mapping
   - Water Quantity Estimates

II. Supply/demand balance
   - Alternative water resource
   - Facilitating industry reuse

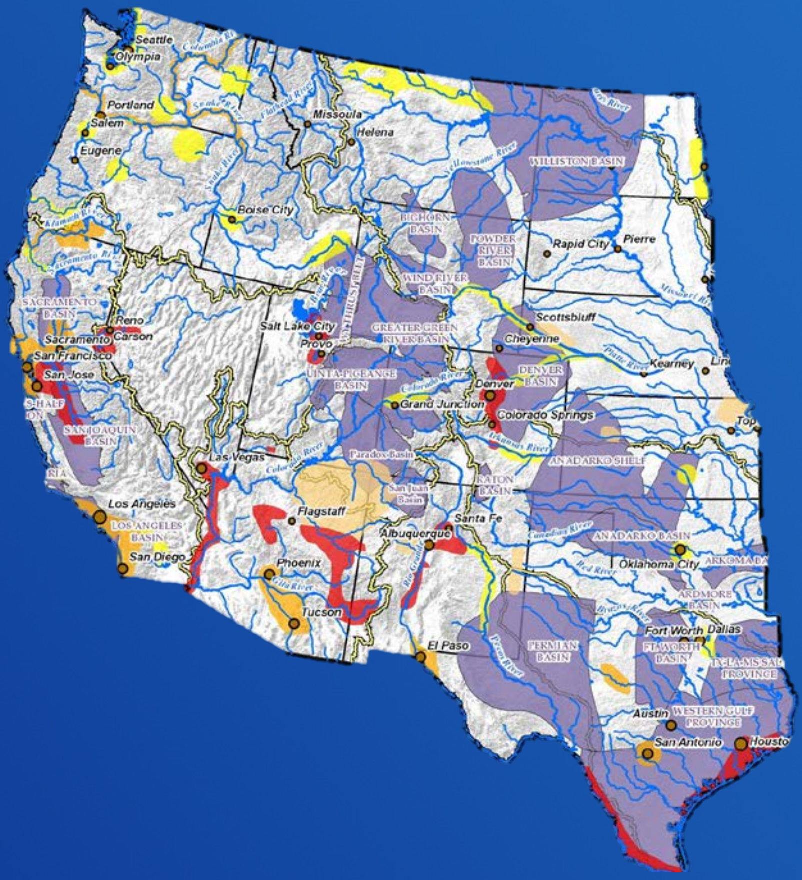
III. Water Treatment Plants
   - Matching Appropriate Technology
   - Developing/implementing innovative technologies
   - Demo/Pilot Study Examples



Locations of Opportunity

Information for water managers to assess:

- Production locations
- Produced volumes
- General water quality
- Potential water management opportunities:
  - Beneficial use
  - Conveyance systems
  - Disposal options
  - Facility co-location



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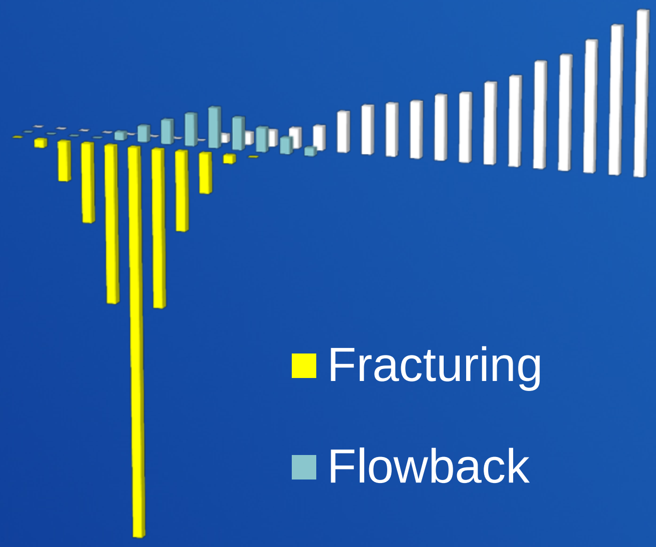
Supply and Demand Balance

- Direct reuse of hydraulic fracturing flowback and produced water
  - Compatible with the producing formation
  - Available on-site (reduces transport cost)
  - Reduces disposal wells
- Brackish groundwater as an alternative to fresh water for fracturing
- Industrial/commercial reuse sources
  - Increased volume in water ways
  - Free/natural conveyance system

Qualifying Water Demand and Production over a Well Lifetime



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Existing Water Treatment Plants

Case Studies of Existing Hydraulic Fracturing Flowback and Produced Water Treatment Facilities

- Facility Description
- Location
- Feed Water
- Capacity
- Treatment Process
- Treated Water Use
- Concentrate Disposal
- Operational experience
- Performance data
- Permits

McKean County, PA

San Ardo, CA

Clarion County, PA

Wellington, CO

Pinedale, WY

Powder River Basin, WY

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On-going Research Efforts

Collecting Information:

- Published Studies (Department of Energy, US Geological Survey, Argonne National Labs, National Energy Technology Laboratory, A&E)
- Regulatory Guidelines (Environmental Protection Agency Centralized Waste Treatment Facilities for Oil and Gas)
- Reclamation Experience (Missouri River Bakken Shale Fracturing Water Supply Agreements)
- Commercial Treatment (Commercial Technology Survey, Technology Evaluation at Reclamation Facilities)
- Industry Collaboration (Industry Water Management Expertise Survey, Produced Water Treatment Community of Practice)

Research Project Websites:

- http://www.usbr.gov/research/projects/detail.cfm?id=1617
- http://www.usbr.gov/research/projects/detail.cfm?id=3259
- http://www.usbr.gov/research/AWT/reportpdfs/report157.pdf

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Contact Information

Katharine Dahm, Kdahm@usbr.gov, 303.445.2495

Katie Guerra, Kguerra@usbr.gov, 303.445.2013

Bureau of Reclamation

Technical Service Center

Advanced Water Treatment Research

Denver Federal Center

Denver, CO 80225

U.S. Department of the Interior

Bureau of Reclamation