RECLAMATION Managing Water in the West

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

April 10th, 2013 AWWA Sustainable Water Management Conference

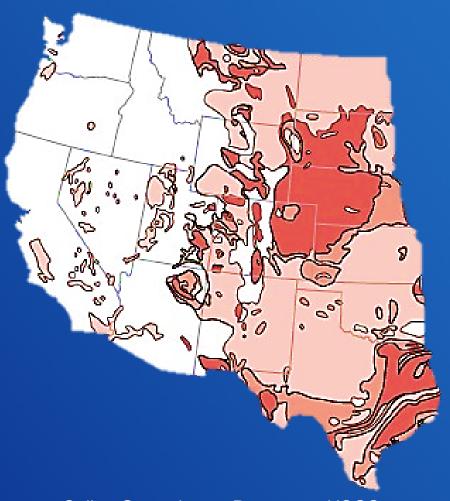
Katharine Dahm Katie Guerra



U.S. Department of the Interior Bureau of Reclamation

Bureau of Reclamation

- 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)

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

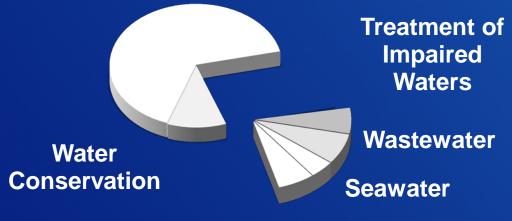


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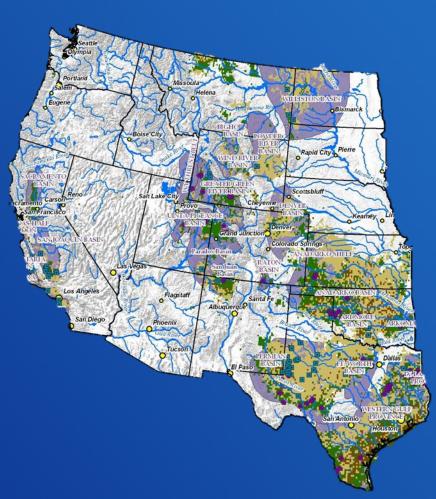
Where do we fit into produced water?

Western Water Portfolio

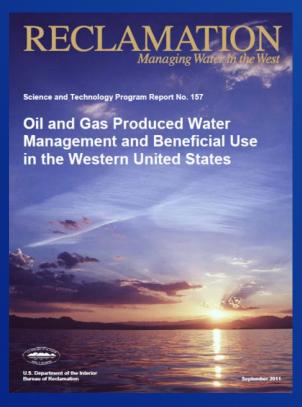
Existing Supply

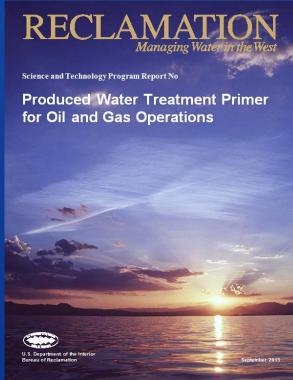


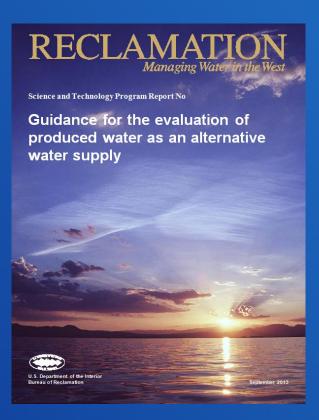
Produced Brackish water water



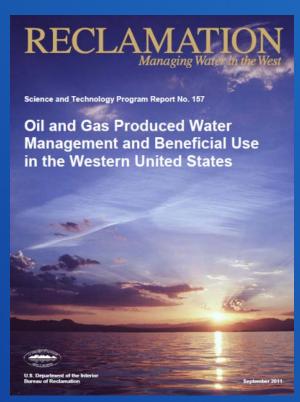
Reclamation (2011), Conventional Oil and Gas





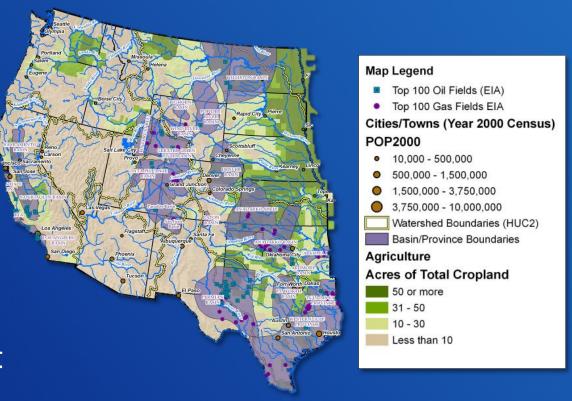


- I. Beneficial Use Opportunities
 - Production Locations
 - Water Quality Requirements
 - GIS Based Examples
- II. Produced water characterization
 - Produced Water Volumes
 - Produced Water Quality
- III. Water treatment technologies
 - Technology Assessments
 - Technology Comparison



Beneficial Use Opportunities in the western US

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



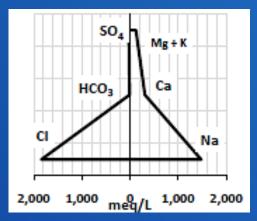
Reclamation (2011), Agricultural areas overlaid with O&G basins

Produced Water Characterization

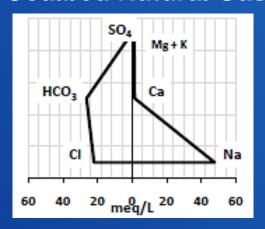
Table 13. Common inorganic constituents in conventional produced water

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

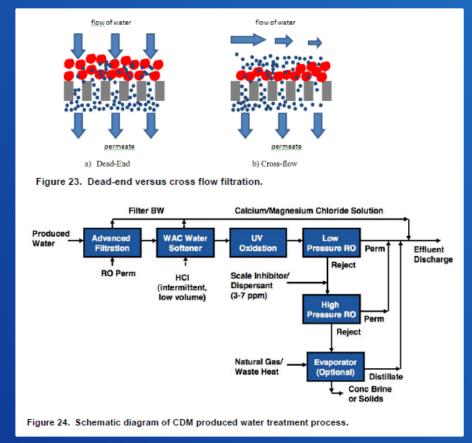


Coalbed Natural Gas



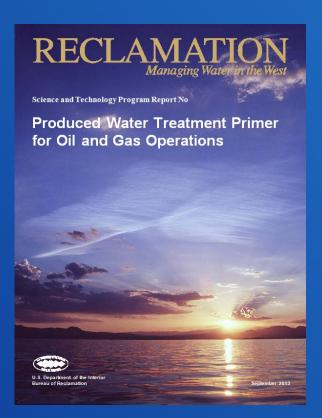
Water Treatment Technologies

- 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™



Reclamation (2011), Produced Water Treatment Technology Schematics

- 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	I		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'	Reliability ²	Flexibility ^a	Mobility	⁴ Modularity ⁵	Residual Disposal/ Manage- ment
Membrane				r		
NF	++	+++	++	++	Yes	+
RO	++	+++	++	++	Yes	+
ED/EDR	+	+++	+	++	Yes	+
	1.	, ,	-	<u> </u>	-	

Table 20. Compariso	n of organi	c contamina	nt and par	ticulate removal	technole	ogies for t	eatme	nt of pro	duced w	ater										
Technology	Emerging Technology	Phenously Employed for Produced Water	Overall Process Recovery (%)	Conteminents removed	Organic Matter Removal	Perticulate Removal (min size removed)	Heavy Metals	Low Chemical Demand	Low Energy Demand	Minimal Maintenance	Ease of Operation	Ninimal Postheatment Requirement	Low Cost	Robustness*	Fishebility ²	Flootsity ³	Mubility ⁴	Modularity ⁸	Waste Disposal Requisiments	Small Footprint
Biological serated filters	No	Yes	100%	ol, ritrogen, 000, pap	++	**	+	+++	***	+++	***	+	+++	+++	+++	+++	-		**	
Hydrodone	No	Yes	98%	pertruktes	NA.	5-15 um	-	+++	+	+++	***	+++	+	+++	+++	+	+	-	**	++
Centrifuge	No	Yes	98%	perticulates	NA.	2 um	-	+++	+	+++	+++	+++	+	+++	+++	+	+	-	++	++
API gravity seperator	No	Yes	99%	perticulates	NA.	150 um	-	***	+	***	***	111	+	***	111		+	-	**	++
Corrugated plate separator	No	Yes	93%	perticulates	NA.	40 um	-	***		***	***	+++	+	+++	+++	+	+	-	**	**
Dissolved singss flotation	No	Yes	100%	TOC, oil and presse, particulates, hydrogen sufide	***	3-25 um	-	***	**	**	***	***	**	**	***	٠	+	-	**	**
Adsorption/media filtration	No	Yes	99%	periodates, BTEX, sit, TOC, iron, manganese, heavy metals.	***	5 um	**	***	***	**	***	+++	**	***	***	***	***	***	**	**
Oridation	No	Yes	100%	menganese, iros, sulfur, color, odor, synthetic organic compounds	**	NA.	**	**	**	**	**	***	**	***	***	***	***	***	***	***
Setting pond	No	Yes	100%	perticulates, iron, manganese	NA.	+++	++	+++	+++	+++	+++	+++	+++	+++	+++	++	-	-	+++	-
Air stripping	No	Yes	100%	TOC, votable organics	+++	NA.	-	+++	++	++	++	+++	++	+++	+++	+	++	+	+++	++
Surfactant modified position vapor phase bioreactor	Yes	Yes	99%	TOC, volstle organice	***		**	**	***	***	***	***	ND	ND	ND	ND	ND	***	**	++
Constructed wetlands	No	Yes	100%	TOC, dissolved organic compounds (increased calcium and slighty increased TDS)	***	***	**	***		***	***	***	***	***	***	**			***	
Granular activated carbon fluidized bed reactor	No	Yes	100%	TCC, voteble organics	+++	**	***	***	***	**	***	+++	+	***	***	+++	***	***		***
UV disinfection	No	Yes	100%	machinen of microbal contaminants	NA.	NA.	NA.	***	٠	+	***	***	+	٠	***	***	***	***	***	***
Coramic MFAUF membrane	Yes	Yes	85 to 95%	particulation, dissolved (with coagulation) and suspended organice, biological contaminants	**	0.01 um		**		**	**	***	**	***	**	**	***	***	**	**
Polymeric NFILF membrane	No	Yes	85 to 95%	particulaties, dissolved (with coagulation) and suspended organics, biological contaminants	**	0.01 um	-	**		**	**	***	**	+	**	**	***	***	**	**
Legend:	Excellent	5100	Fair	Ploy]															
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Sectrology	Emerging Technology	Previously Employments Produced Willer	Approator Kange	Oversil TDS Reputer (%)		For Participal Control	Organica	Hauteng Meripine	Mong Paragrant Regard	Line Chemical Chemical	Low Energy Demand	Morral Merterance	Ease of Operation	iow Out	Fotouriness'	Facianty ²	Feeting!	Missing*	Work, lawly	Provius Deposed Manage- ment	r polym
Merchan	_	_	1,000 to 36,000			_	_	_	_		_	_	_	_	_	_		_		_	, -
W.	No.	784		> 90	40 to 50			**		**				**	**	***		**	Tes		**
10	No	Yes	1.000 to 35.000	=99	10 to 60	***	-	***	_	**	-				**	***		**	Yes	-	**
DECR	Yes	Ym	50010 1,500 +500	55 N 15	89 to 90		-	**	**	10	160	100	:	100	10	100		**	Title		
Nordoste Nybri		Ne	- 500	95	140	**		10	_	10	140	160		10	NO.	10	10	ND	700	140	10
iche	No	Ne	25.000 - 50.000	- 90	30 to 44	**	-	**						10	**	***	**	**	Yes		**
Delt ROW Demost Proop	Yes	No	1000 to 35,000	>64	60	***	٠	***	-	-	140		٠	10	**	***	**	**	Yes		**
Dat ROWHERD	Yes	The .	1000 to 35,000	>14	90	***	٠	***		**			٠	10	**	***	**	**	796	٠	**
DUE FOR	Yes	No	1000 to 10,000	>54	90	***		***	-	**	160			NO	**	***	**	**	Yes		**
HEED	Tes	Yes	+900	NO.	160	+		**	**	***	***	+	+		+	ND.		++	Tes	+	
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Therital	_	_			_		_	_					_			_	_	_	_		_
MIP	Pai	7	1-000 to 10-100	>30.0	27 6 40	***		**						**	**				70		
MEO	761	· ·	1 500 to 50 000	> 20.9	20 to 40	***	-	**						**	**			-	70		
irc	766	716	1.500% 50.000	+ 30.9	90	***	-	**						**	**			_	Tes	-	
MED-VC	NI		1.500 to 50 000	> 30:9	27 to 40	***	-	**						**	**			-	760	٠	
Ю.	Yes	No	500 to 50,000	>365	MD	**		10		**	ND.	NO.		**	10	ND	10	ND:	Yes	ND	140
Fronte Trax	File	Yas	> 8-600	>54	Qui	***		***	**	***	**		**	**	**	***		_	- 100		<u> </u>
Abenetive	Yes	Yes	500 to 5 000	- 65	56 to 85	***		10			**								Yes		
W .	7au	Total	+ 750	90	95.9	**	-	***	-	-	***	-					-	***	740	-	-
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othering							_										_	_	_	_	_
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9040906	Yes	760	11750	195	248	A/A	24	***	***	***	160	160	***	100	**	100	-	-	700	*	+
Nine Fair	785	Yes		190	148	748.	AA.	***	**	***	***	**	***		10	160	16	140	100	***	÷
12 Persuses	Yes		+7.500	190	1/4	NA.	20	***	***	105.	160	100	**		10	10	10	ND.	- 70	***	
Dispession .	- Pari	Tes	+1.250	760	248	NA.	2.0			***	***			***	***	***			-	***	
MACC.	Yes	766	11.250	760	148	NA.	34	***	***	111	100	100	***	100	***	100	-	+	700	***	+
Development	798	769	911,250 900 to 45,000	30	168	nya.	24	***		***	100	NO.	***	NO +	10	100	100	190	766		÷
SAL-FROC ^{TO}	790	7ms	×7.500	194	NA.	rya.	AA.	***	***	tu.	160	160	**	-	10	NO NO	10	ND ND	700	***	÷
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Development and Implementation of Water Treatment Technologies

Water Treatment



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

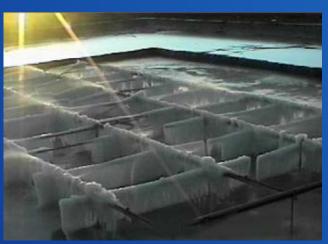




Reclamation Funding of Produced Water Treatment Technologies

- 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 us 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 the resistance, etc.) [1]
- Water and ambient
 Trustrulence in general
- Turbulence in gase
- Area-to-volume rati
 Exposure time
- Lxposure 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: Diffusion Type Aerators: Mechanical Aeration: sur

Spray aerators dissipate wa Multiple-tray aerators use τ

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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 H₃S [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 amons or cations make separation possible [2]. ED uses these membranes in an alternating fashion to create concentrate and product treams.

The amions are able to pass through the amion-selective membrane, but are not able to pass by the cation-selective membrane, which blocks their path and traps the amions 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 amon-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 sitica [4].

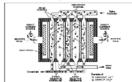
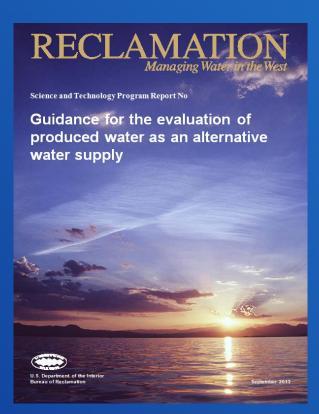


Figure 1. Electrodialysis Process [1].

USAID

Electrodialysis 1

- 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:

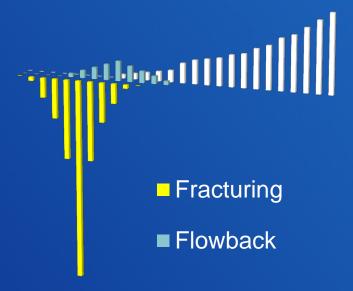
- Production locations
- Produced volumes
- General water quality
- Potential water management opportunities:
 - Beneficial use
 - Conveyance systems
 - Disposal options
 - Facility co-location



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



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



Clarion County, PA



Pinedale, WY



San Ardo, CA



Wellington, CO



Powder River Basin, WY

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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Bureau of Reclamation
Technical Service Center
Advanced Water Treatment Research
Denver Federal Center





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