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Brackish Water as a New Water Resource For Developing Domestic Energy

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Overview

- Energy issues with water and its associated costs for development
  - Drought conditions are requiring the investigation of different water sources
  - Water required for unconventional plays for oil and gas – 60,000 to 650,000 gals per well for drilling
  - Water required for hydraulic fracturing of 3,5 MG to 5 MG per well
- Is the drought in western US an issue with energy development?
- What issues need to be solved in the future?

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Discussion Outline

- Introduction
- Volumes and Quality of water required for energy development
- Water conflicts with energy development
- Role of agriculture
- Cost implications
- Summary

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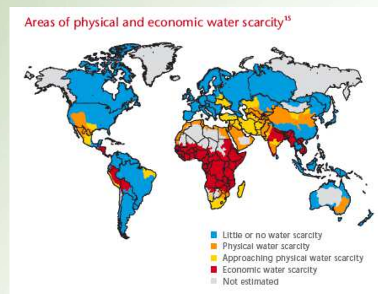
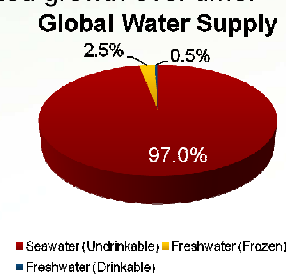
The global situation for water is not improving and will be an impediment to industrialized growth over time.





World Business Council for Sustainable Development

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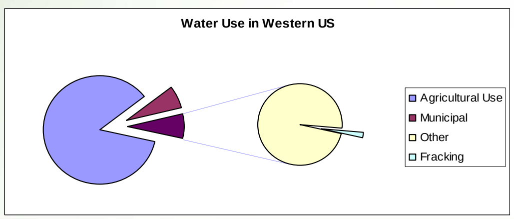
Water Use as a Function of Overall Water Management

- What is the percentage of total fracking and energy development = **0.14% of total** use in the US typical - (example is Colorado)
- Largest use is Agricultural at 85%
- Second highest use is Municipal and Industrial at 7%
- All others is 8%
- This 0.14% equals the amount of water used on an annual basis by the City of Denver.



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So what is the issue? Can't we get more water from Agriculture?

Fracking Companies Outbid Farmers for Water - Denver Post March 2012

- Agricultural use is increasing
- Environmental groups are fighting fracking and energy development in general
- Agricultural use has to increase
- Issue with the Sacramento River Delta
- Municipal uses are increasing
- Oil and Gas can out bid all others
- Water from Agriculture or Municipalities will be a public relations nightmare

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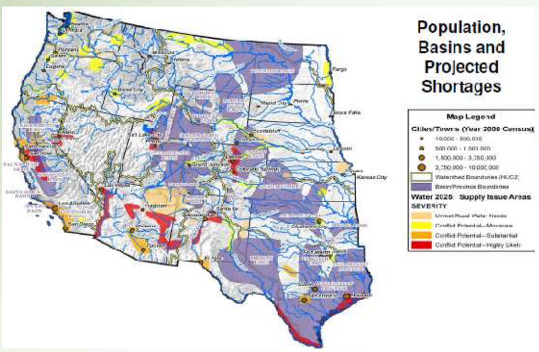
Example of Projected Water Shortages



- Areas of red are water short
- Note that in the western US, there is an opportunity to utilize produced water for beneficial use

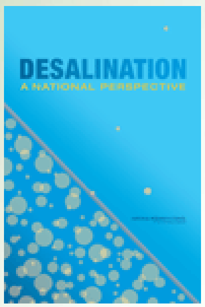
Reference: USBR - Water 2025 Study

Where can we get new water for energy development?

General Categories of Saline Water	
Freshwater	less than 1,000 ppm
Slightly saline water	from 1,000 to 3,000 ppm
Moderately saline water	from 3,000 to 10,000 ppm
Highly saline water	from 10,000 to 35,000 ppm
*Ocean water contains about 35,000 ppm of salt	

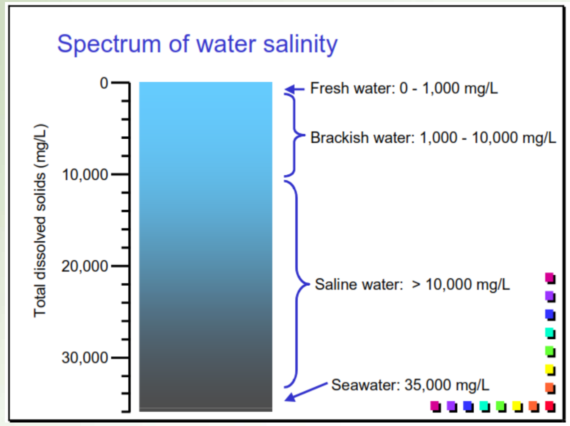
- Brackish water – 1,000 to 10,000 ppm of TDS
- Treatment up to 75,000 ppm
- Produced water reuse – discussed in another presentation on Wednesday
- Reuse of other types of wastewaters

Brackish Water in the US



- Efforts to find new untapped water supplies in the US
- NAS study on desalination
- Constraints are not the technology, but the financial, environmental and social factors
- Participation is needed by all in the development of this resource to limit any significant issues associated with this treatment

Resources



Produced water can be as high as salt saturation at 320,000 mg/l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Resources
Inland Desalination a Now-Attainable Solution
Saline Aquifers
Source: U.S. Geological Survey
These aquifers extend into Mexico as well
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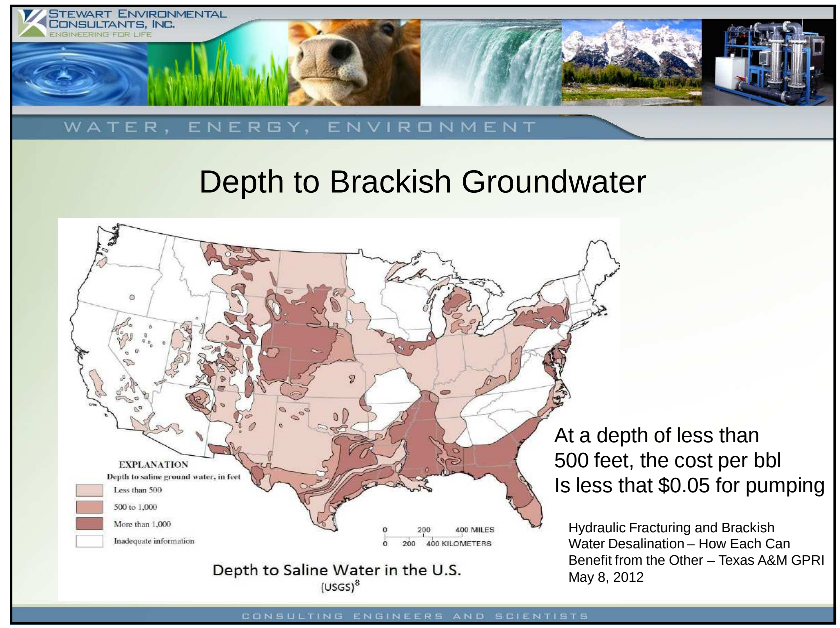
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Depth to Brackish Groundwater
EXPLANATION
Depth to saline ground water, in feet
Less than 500
500 to 1,000
More than 1,000
Inadequate information
0 200 400 MILES
0 200 400 KILOMETERS
Depth to Saline Water in the U.S.
(USGS)8
At a depth of less than
500 feet, the cost per bbl
Is less that $0.05 for pumping
Hydraulic Fracturing and Brackish
Water Desalination – How Each Can
Benefit from the Other – Texas A&M GPRI
May 8, 2012
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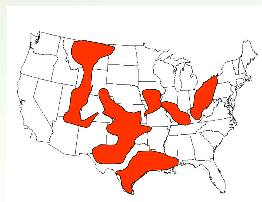
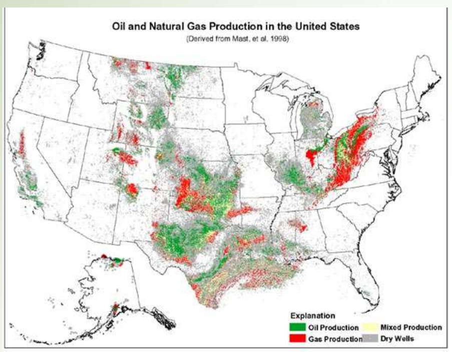
Resources

Oil, Gas and Coal Basins





- Opportunity to convert produced water disposal cost to new water supply

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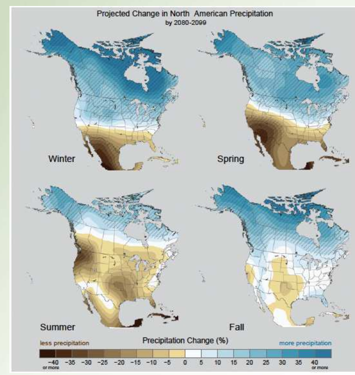
Drought Projections in North America



- Data from UN
- Note the movement of water to the north due to climate change predictions

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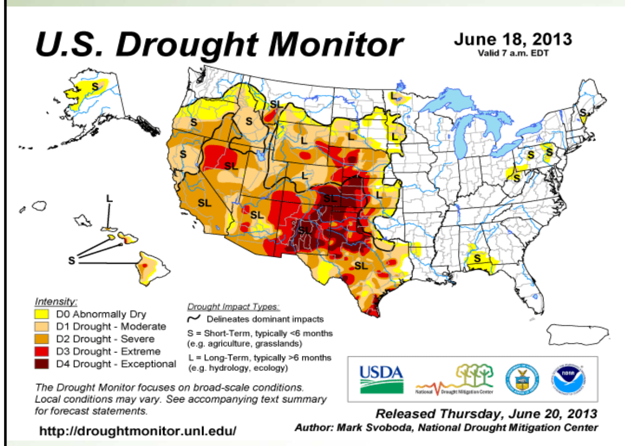
Problem



- Drought is still a significant issue
- Energy Development can demand water in short supply

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What is the impact of the drought on energy production -Texas Example

- ❖ Availability of water in Permian Basin with extended drought
  - ❖ Colorado River basin issues
  - ❖ Municipal water supplies are stretched already
    - ❖ Lake JB Thomas **0.50% full (0.1% 6 months ago)**
    - ❖ EV Spence Reservoir **5.1% full (0.2% 6 months ago)**
    - ❖ OH Ivie Reservoir **20.7% full**
- ❖ Requirement for District is to supply **water for drinking and public safety** – water for E&P operations is not a concern and very limited at this point
- ❖ "If you don't have water, you can't attract industry" – Guy Andrews – Economic Development Director – Odessa Texas

Full Reservoir

Current Conditions

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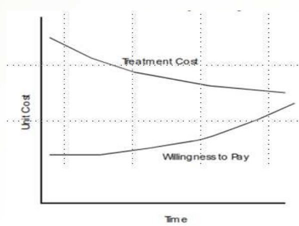
Problem / Opportunity

- Water supply is a limiting factor to industry
- Demand leads to increased willingness to pay for water
- Improvements in treatment technologies lead to reduced costs (both capital and O&M)
- Convergence of these factors leads industry to source alternative lower quality water
- New opportunities are created in processing and appropriating water to highest and best use.

Discussion regarding the water – energy – agricultural nexus



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Technology

Water Resources May be Augmented by New Technology

"The single most frequent failure
in the history of forecasting has been
grossly underestimating
the impact of technologies"

Peter Schwartz from
The Art of the Long View

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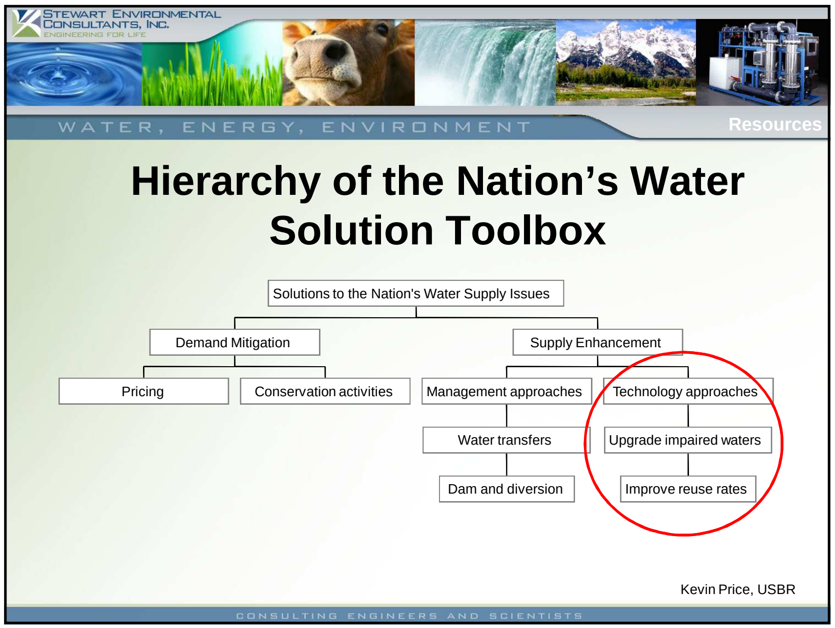
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Resources
Hierarchy of the Nation's Water Solution Toolbox
Solutions to the Nation's Water Supply Issues
Demand Mitigation
Supply Enhancement
Pricing
Conservation activities
Management approaches
Technology approaches
Water transfers
Upgrade impaired waters
Dam and diversion
Improve reuse rates
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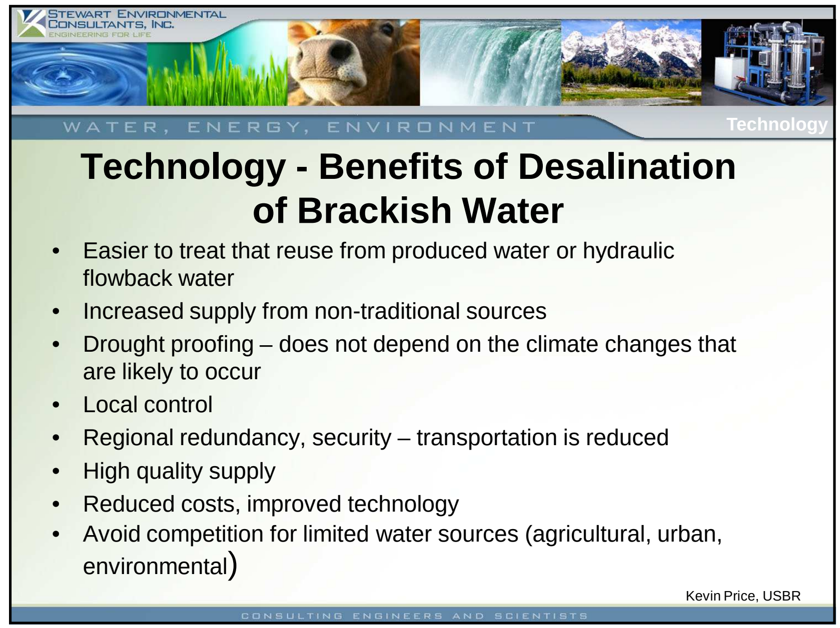
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Technology - Benefits of Desalination of Brackish Water
• Easier to treat that reuse from produced water or hydraulic flowback water
• Increased supply from non-traditional sources
• Drought proofing – does not depend on the climate changes that are likely to occur
• Local control
• Regional redundancy, security – transportation is reduced
• High quality supply
• Reduced costs, improved technology
• Avoid competition for limited water sources (agricultural, urban, environmental)
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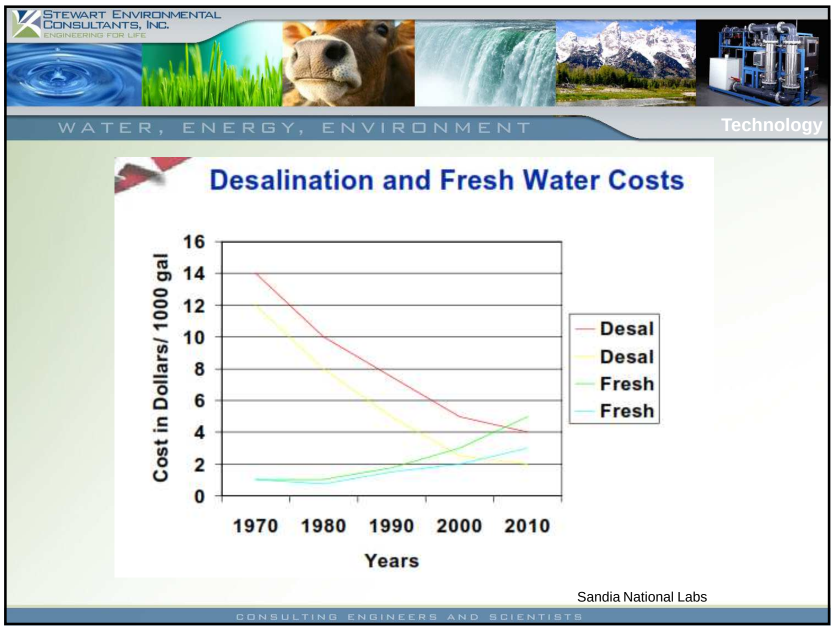
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Desalination and Fresh Water Costs
Cost in Dollars/ 1000 gal
16
14
12
10
8
6
4
2
0
1970
1980
1990
2000
2010
Years
Desal
Desal
Fresh
Fresh
Sandia National Labs
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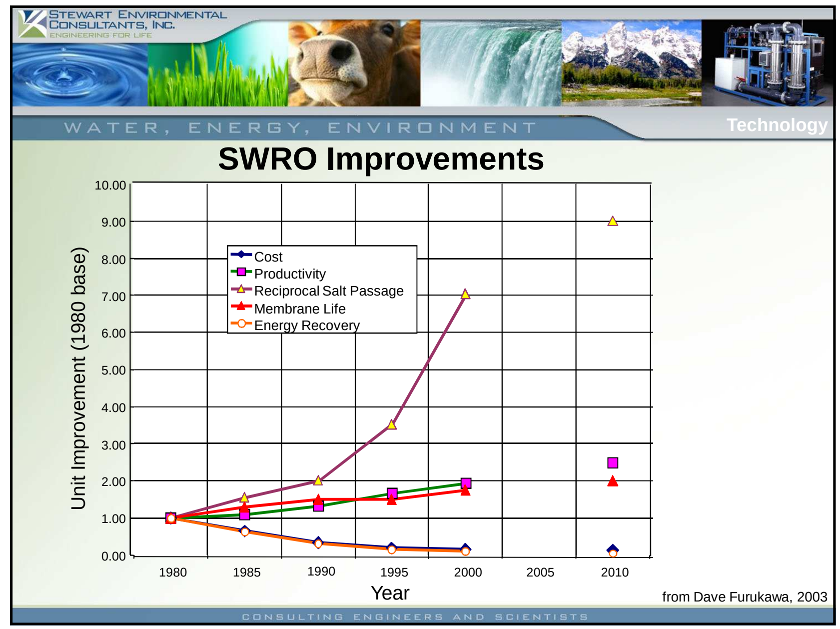
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Technology
SWRO Improvements
Unit Improvement (1980 base)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1980
1985
1990
1995
2000
2005
2010
Year
Cost
Productivity
Reciprocal Salt Passage
Membrane Life
Energy Recovery
from Dave Furukawa, 2003
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Water Supply Options	Cost (US $/1,000 gal)
Demand Mgmt/Repair leaks	$0.38 – 2.65
Desalination of Brackish water	$0.75 – 1.50*
Wastewater reuse & Produced Water Reuse	$0.38 – 3.75
Long distance transfer	$1.15 - $3.75
Desalination of Sea Water	$2.25 – 3.60

* Very dependent on chemical make up of brackish water

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Impaired / Brackish Water – Highest & Best Use

Current Best Uses of Brackish / Impaired Ground Water
- Energy Exploration Water
- Industry
- Power Production
- Drought Reserve
- Agriculture

Current Best Uses of Produced Water
- Energy Exploration Water
- Industry
- Agriculture

Portfolio of Water Rights is the key to success – brackish water can be part of the porfolio

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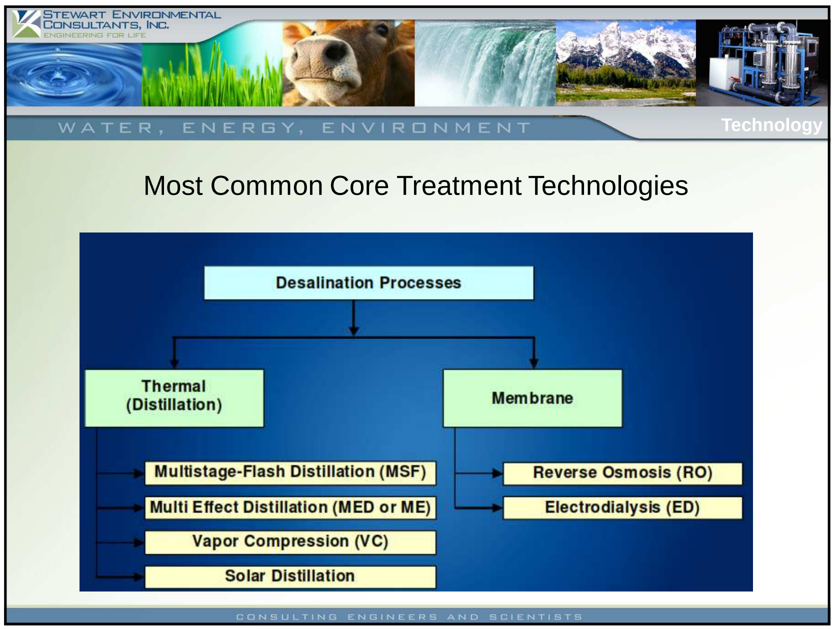
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Technology
Most Common Core Treatment Technologies
Desalination Processes
Thermal (Distillation)
Membrane
Multistage-Flash Distillation (MSF)
Multi Effect Distillation (MED or ME)
Vapor Compression (VC)
Solar Distillation
Reverse Osmosis (RO)
Electrodialysis (ED)
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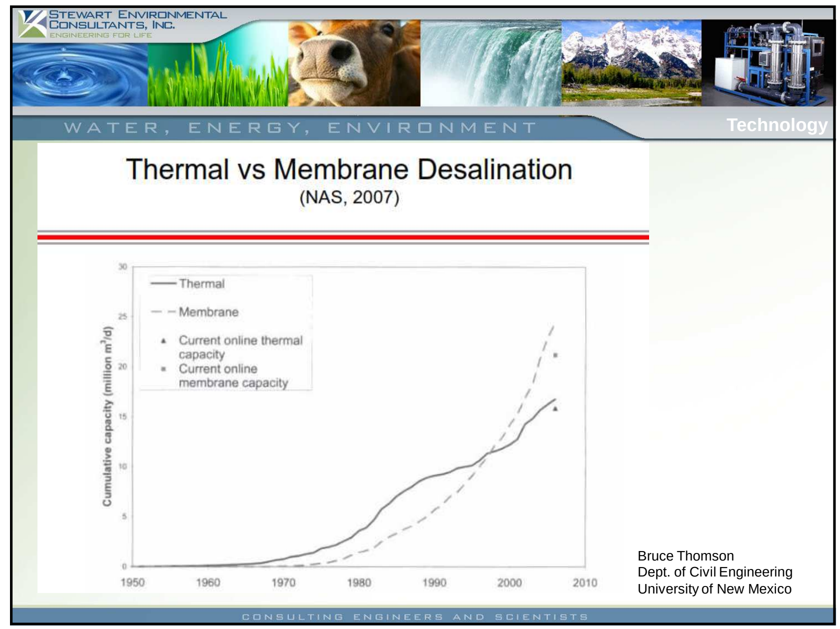
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Technology
Thermal vs Membrane Desalination
(NAS, 2007)
Thermal
Membrane
Current online thermal capacity
Current online membrane capacity
Cumulative capacity (million m³/d)
0
5
10
15
20
25
30
1950
1960
1970
1980
1990
2000
2010
Bruce Thomson
Dept. of Civil Engineering
University of New Mexico
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Inland Impaired Brackish Water vs. Seawater

- Inland Waters are new frontier, seawater is relatively defined
- Major differences include:
  - Treatment & Recovery Objectives
    - Brackish can recover over 90% of the water – 10% brine solution
  - Water Chemistry
    - Removal of scale formers insitu is the most important item for treatment
  - Brine Disposal Options
    - Recovery of rare earth minerals such as lithium

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Inland Impaired Brackish Water

- Highest & Best Use may not include desalination / RO
  - In a lot of projects, NF can be used in place of RO
  - Removal of scale forming compounds
- Factors Limiting High Water Recovery:
  - Brackish inland water contains numerous ions
    - Anions: Sulfate, Fluoride, Carbonate…
    - Cations: Calcium, Strontium, Barium…
  - High Recovery concentrates ions through use of sequestration techniques
  - Salts precipitate at solubility
- Osmotic pressure increases with recovery > applied pressure

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Membrane Fouling

- Membrane Filtration Plants are challenged with fouling
    - Colloidal, Inorganic, Organic, Biological
- Inorganic fouling is most challenging
- Colloidal particles are also important and can cause issues for membranes
- Inland impaired/brackish water may cause all four fouling types
- New treatment unit process designs can minimize issues
- Impaired / Brackish water chemistry is very dynamic
    - No single process is ideal for all treatment

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Variation of Water Types

Table 1. Compositions of Seawater and Inland Brackish Sources – (mg/L)

Composition	Seawater Reference	Groundwater Tularosa Basin, NM	Groundwater Las Vegas, NV	Groundwater Hueco Bolson, TX	Wastewater Plant Stream Rio Rancho, NM
Na	10800	114	755	116	150
K	390	2	72	7	25
Ca	410	420	576	136	36
Mg	1300	163	296	33	51
Cl	19400	170	954	202	142
NO_3	NR	10	31	NR	79
PO_4	NR	0	NR	NR	20
SO_4	2710	1370	2290	294	110
HCO_3	143	270	210	190	110
SiO_2	2.1	22	77	31	32
TDS	**35300**	**2630**	**5270**	**1200**	**640**

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Requirements for hydraulic fracturing makeup water

- Texas A&M Study
  - Need to remove scale forming compounds
- Service companies claims for being able to use high TDS waters
- BP study on low TDS waters for higher recovery of oil/gas – Less than 5,000 ppm TDS

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Scale Forming Salts – Removal Targets

Salt	Saturation Concentration (mg/L)
Calcium Carbonate ($CaCO_3$)	8
Calcium Fluoride (CaF_2)	29
Calcium Orthophosphate ($CaHPO_4$)	68
Calcium Sulfate ($CaSO_4$)	680
Strontium Sulfate ($SrSO_4$)	146
Barium Sulfate ($BaSO_4$)	3
Silica, amorphous (SiO_2)	120

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Difficult Issues for Water Reuse

- ❖Control of scale formers
  - ❖Barium sulfate
  - ❖Calcium carbonate
  - ❖Calcium sulfate (gypsum)
- ❖Control of Salt
  - ❖Discharge to water ways
  - ❖Control of SAR (Sodium Absorption Ratio)
- ❖Control of microbes
  - ❖Difficult filtration issue
  - ❖Sulfate reducing bacteria
- ❖Water injection into Formation – TAMU study
- ❖Water Discharge Issues – CSM RPSEA Study

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Technical Challenges / Opportunities

- •Energy Efficiency
  - •Pressure recovery techniques
- •Osmotic Pressure
  - •Future can use Forward Osmosis
- •Solubility & Scaling
  - •Understanding high salinity precipitation is very important
- •Membrane Process adjustment – highest & best use output
- •Selective sequestration of salts and elements
  - •Fundamental shift – salts/metals as a resource !

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Current Brine Disposal Methods

- Inland –
  - Surface Water Discharge (reuse for energy and agriculture)
  - Evaporation Pond (air pollution issues in the future)
  - Class II Well (Deep Injection Well)
  - Land Application
  - Solid/Hazardous Waste Landfill
- Offshore –
  - Discharge to ocean (very limited in ability to discharge water to the ocean)

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Beneficial Use of Brine / Recovered Materials

- Salt Commodities
  - NaCl, Na_2SO_4, Na_2NO_3, K_2SO_4, $MgSO_4$, KNO_3…..
- Industrial Chemicals
  - Cl_2, NaOH……
- Aquiculture
  - California – recovery of gypsum for clay soils
- Solar Power
- Commodity Metals

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Where does this lead us?

- Non-discharging facilities
- West Texas – SE New Mexico facility example
  - Capitan Reef
  - Need for water for energy production
  - Severe drought in the area
  - Public water supplies are limiting their water resources to only domestic use

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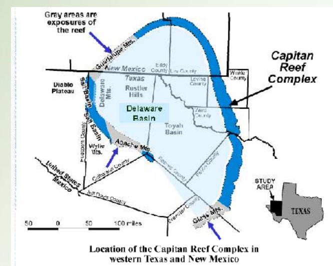
Design Non-discharging Treatment Facilities



- Water saturated with gypsum
- Technology to remove saturated gypsum with RO and Ceramic Microfiltration (patented and trade secret)
- No Waste – water is sold and gypsum is recovered for sale to gypsum mining concern

SMU Conference, 2008,
Prentice Creel, PE

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Economics

- Economics is the key issue
  - Transportation costs will trump costs in most cases
  - This results in facilities needing to be near the energy development site to reduce costs

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Convergence

Connecting the Dots – Appropriation & Sale

Water Law

•Brackish groundwater – surface owner – brackish water in the western US
•Treatment of brackish water for agriculture and potentially for the Monterey Shale Project – Grasslands Basin Drainers project
•Tributary / Non- Tributary – Colorado example

Bottom Line

• Technology Choice is full dependant upon both input and output requirements
•The Market & Technical Drivers have both converged to enable considerable opportunity to those who connect the dots

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Summary & Conclusions – What have we learned?

- Water use for E&P operations is critical to the future of the industry
- Brackish water and water treatment is a viable technology, especially in water short areas
- Brackish water can result in non-discharging facilities
- Brine reuse and recycling should be considered
- Harvesting of metals should be considered in the future to offset costs

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Summary & Conclusions – What have we learned?

- Treatment – becoming more refined
  - Customized to influent characteristics & output req.
  - Mobile or Centralized depending on volumes and transportation
  - Removal of scale forming compounds is key to success
    - Hardness & Metals
    - Carbonates
    - Silica
    - Barium
    - Sulfate/Carbonates
  - If scaling compounds removed, water use may be achieved without TDS removal in some cases (sodium chloride)

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Questions?
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