Desalination

Sam Fernald

Director, NM Water Resources Research Institute

Presented to

SCIENCE, TECHNOLOGY AND TELECOMMUNICATIONS COMMITTEE

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NM WRRI MISSION

- **Serving New Mexico's Water Research Needs**

In response to drought and water scarcity, the NM WRRI was created as a statewide program in 1963 to support water research at NMSU, UNM, and NM Tech. The institute served as a model for institutes nationwide under the federal Water Resources Research Act of 1964. In 2005, the state legislature gave it statutory authority (NMSA 1978 21-8-40) and codified the work with NMSU, UNM and NM Tech as well as other New Mexico universities. It is critical that New Mexico continue to invest in research to solve its water problems.

Changes in U.S. water withdrawals by sector

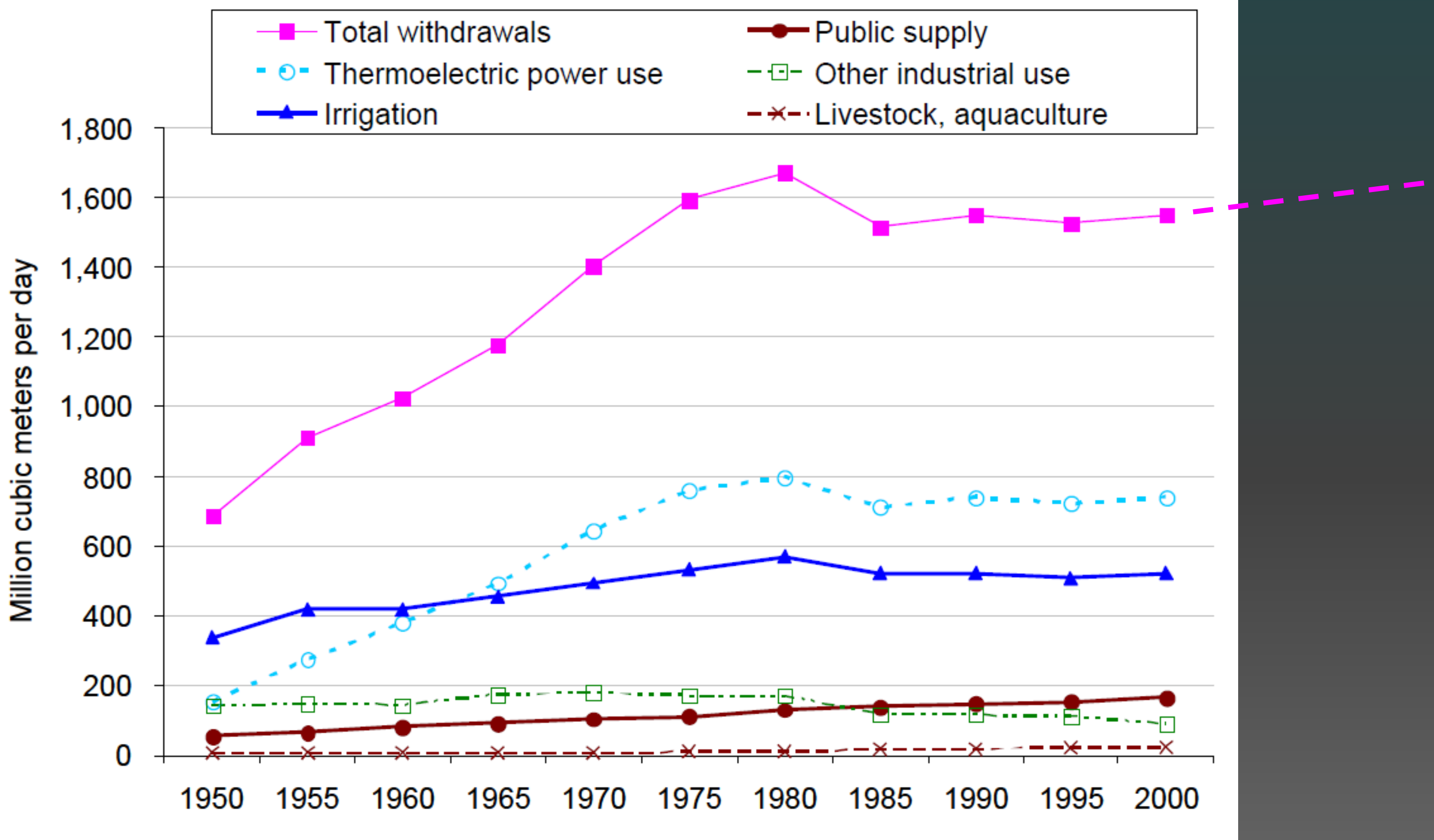


FIGURE 3-3. Changes in U.S. water withdrawals by sector. Data from MacKichan (1951, 1957), MacKichan and Kammerer (1961), Solley et al. (1998), and Hutson et al. (2003).

Data from MacKichan (1951, 1957), MacKichan and Kammerer (1961), Solley et al. (1998), and Hutson et al. (2003).

Overview

A. Desalination basics

B. Alamogordo desalination

C. Where to go from here

  – research and application

Why Desalination?

- Increasing population and increasing water use
- Need to meet future regulations, and environmental needs
- Need for additional, reliable, and safe supplies

The five key elements of a desalination system

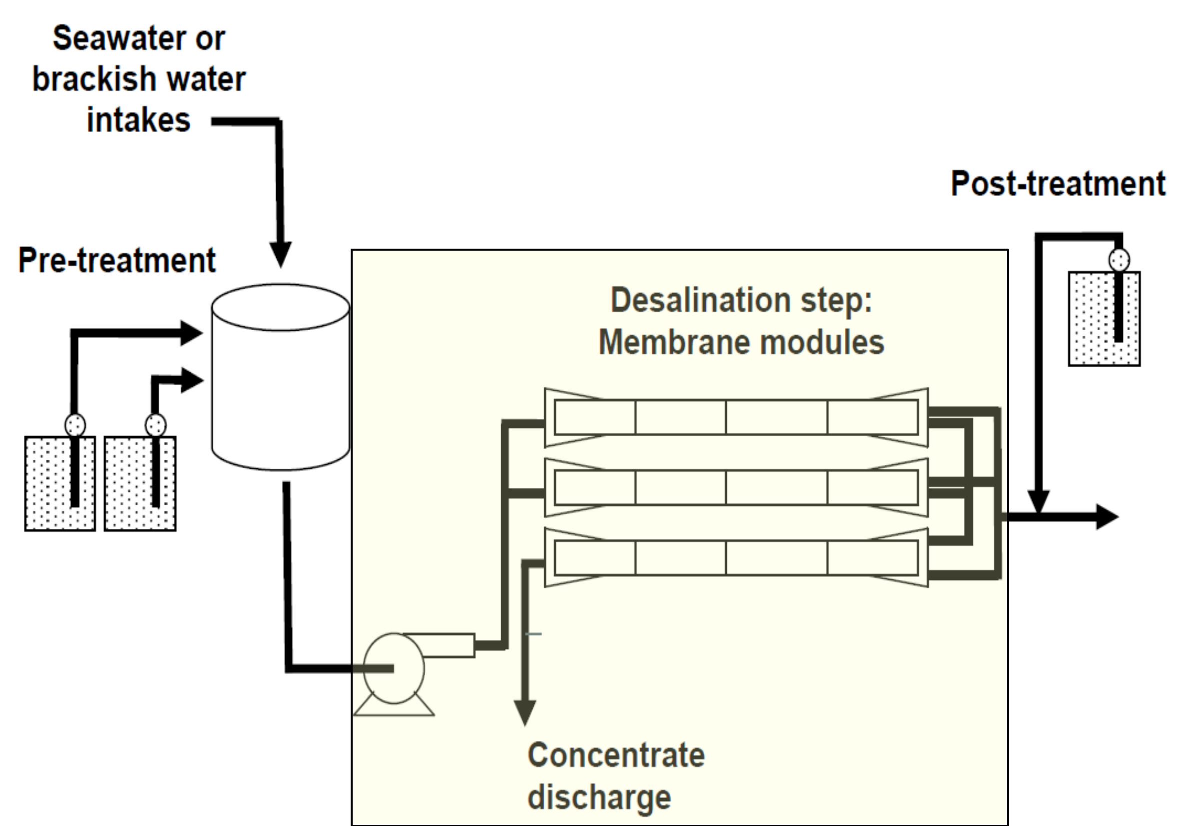
1. Intakes — the structures used to extract source water and convey it to the process system;

2. Pretreatment — removal of suspended solids and control of biological growth to prepare the source water for further processing;

3. Desalination — the process that removes dissolved solids, primarily salts and other inorganic constituents, from a water source;

4. Post-treatment — the addition of chemicals to the product water to prevent corrosion of downstream infrastructure piping; and

5. Concentrate management — the handling and disposal or reuse of waste residuals from the desalination system.

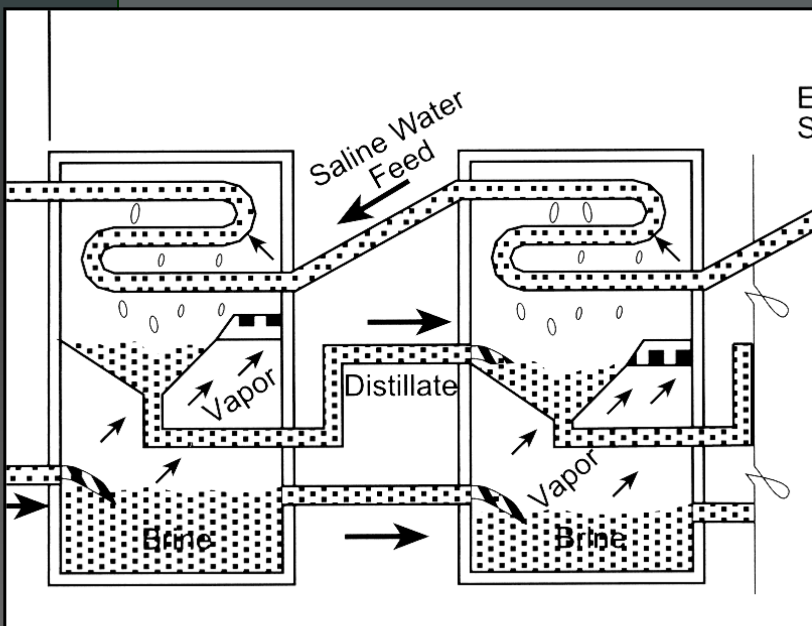


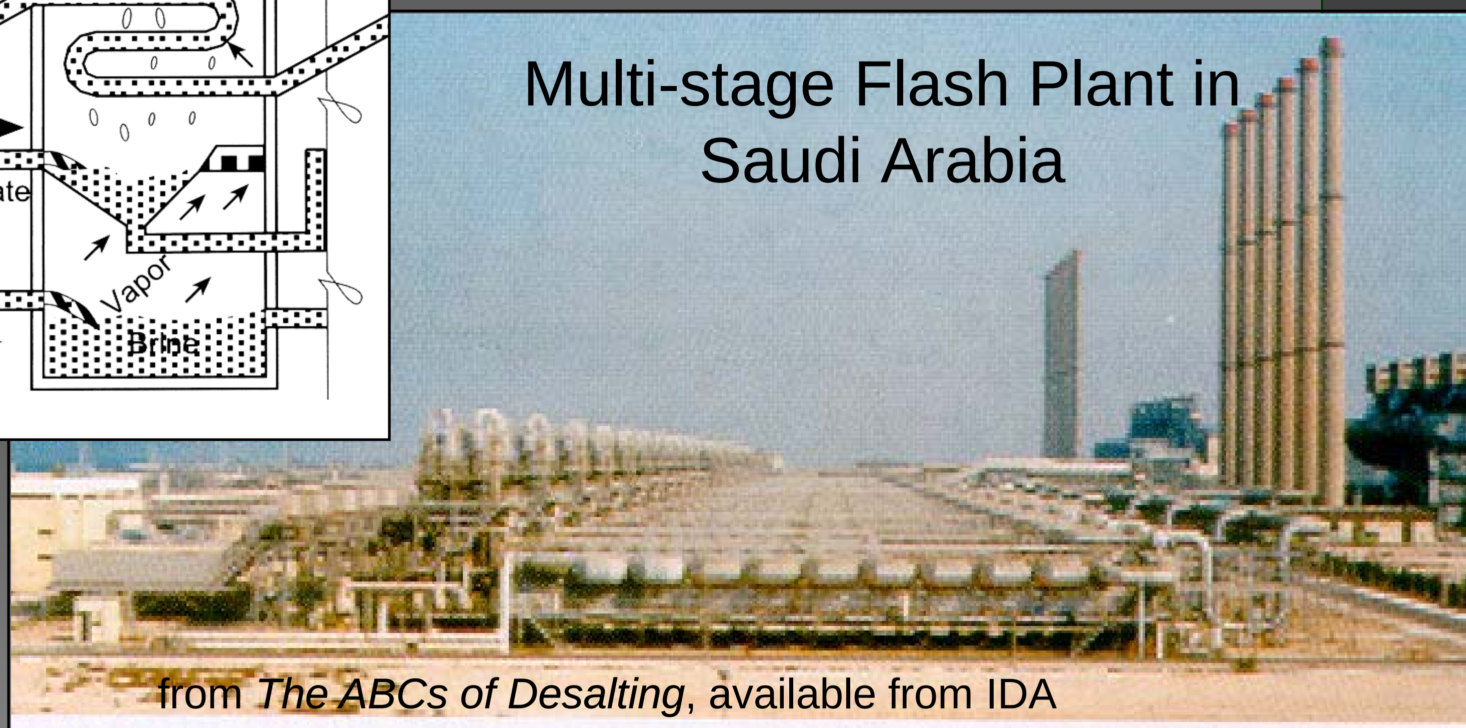
Energy for Desalination

1. Thermal
2. Electrical
3. Chemical
4. Physico-chemical

1.Thermal processes – use heat

- multi-stage flash distillation
- multiple effect distillation
- vapor compression





Multi-stage Flash Plant in Saudi Arabia

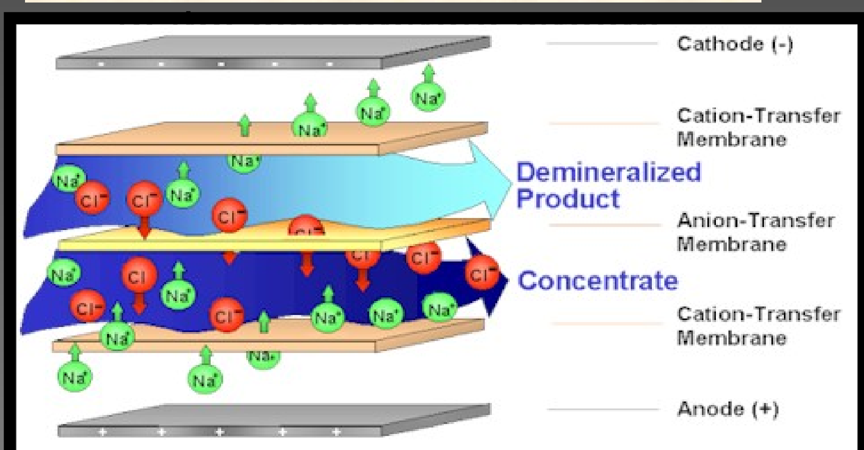
from *The ABCs of Desalting*, available from IDA

2.Electrical

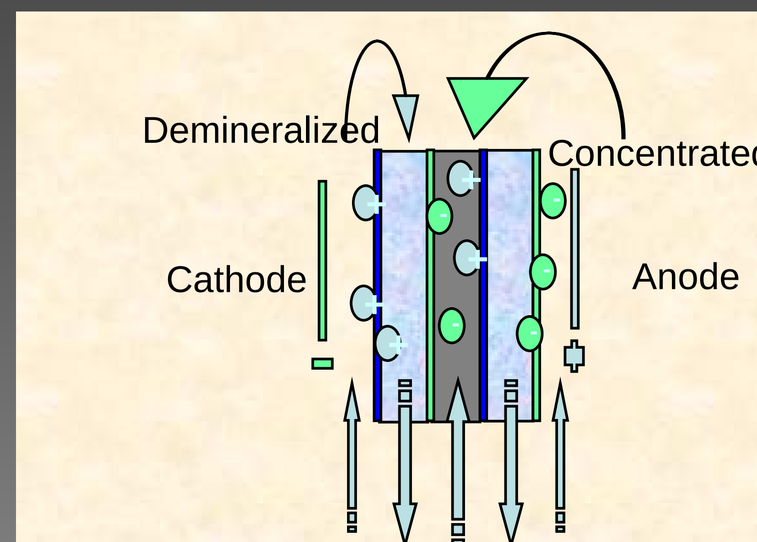
- Electrical potential driven membrane processes
- Ions in solution will migrate toward an opposite charged electrode
- If there is an obstruction preventing re-mixing of the ions, then the de-ionized water can be removed from the vacated solution.

Electrodialysis (ED)

- Uses electrical power to draw ions from product water

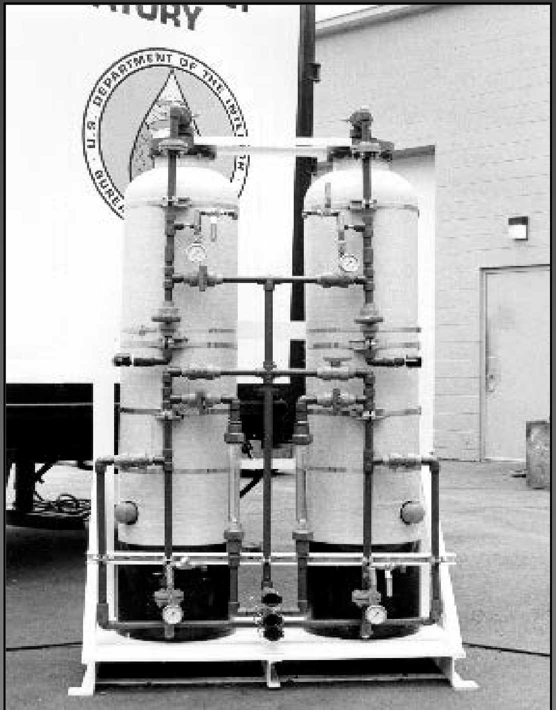


Electrodialysis Reversal (EDR)



3.Chemical Energy: Ion Exchange

- Resin with an affinity toward multi-valent ions is saturated with monovalent ions.
- As water passes through the resin, monovalent ions are replaced with multivalent ions
- As the resin becomes saturated, target ions will begin to bleed through and the resin must be recharged with either NaCl or HCl.
- Not used for Seawater!

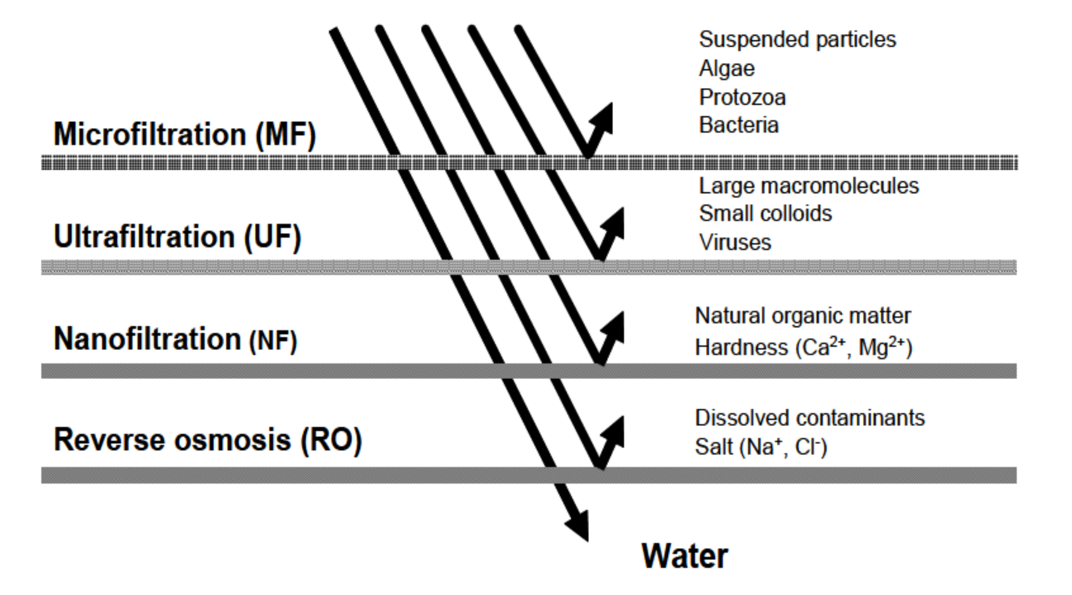


Six gpm Ion Exchange System

4. Physico-Chemical Energy:
Pressure driven membrane processes

- microfiltration (MF)
- ultrafiltration (UF)
- nanofiltration (NF)
- reverse osmosis (RO)

Substances and contaminants nominally removed by pressure-driven membrane processes

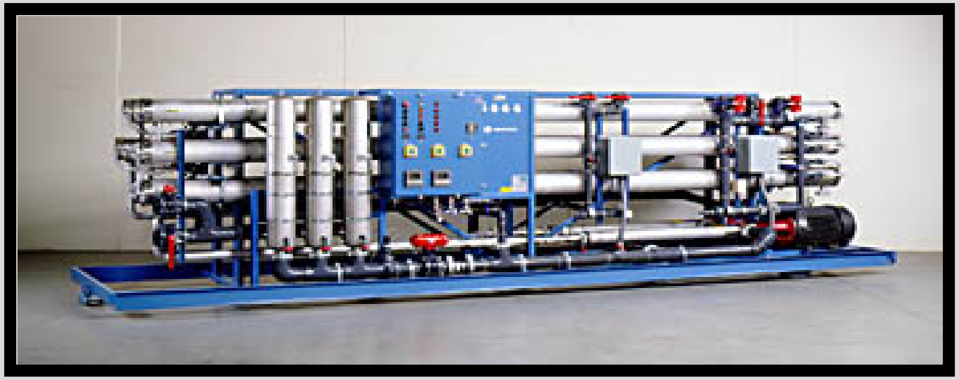


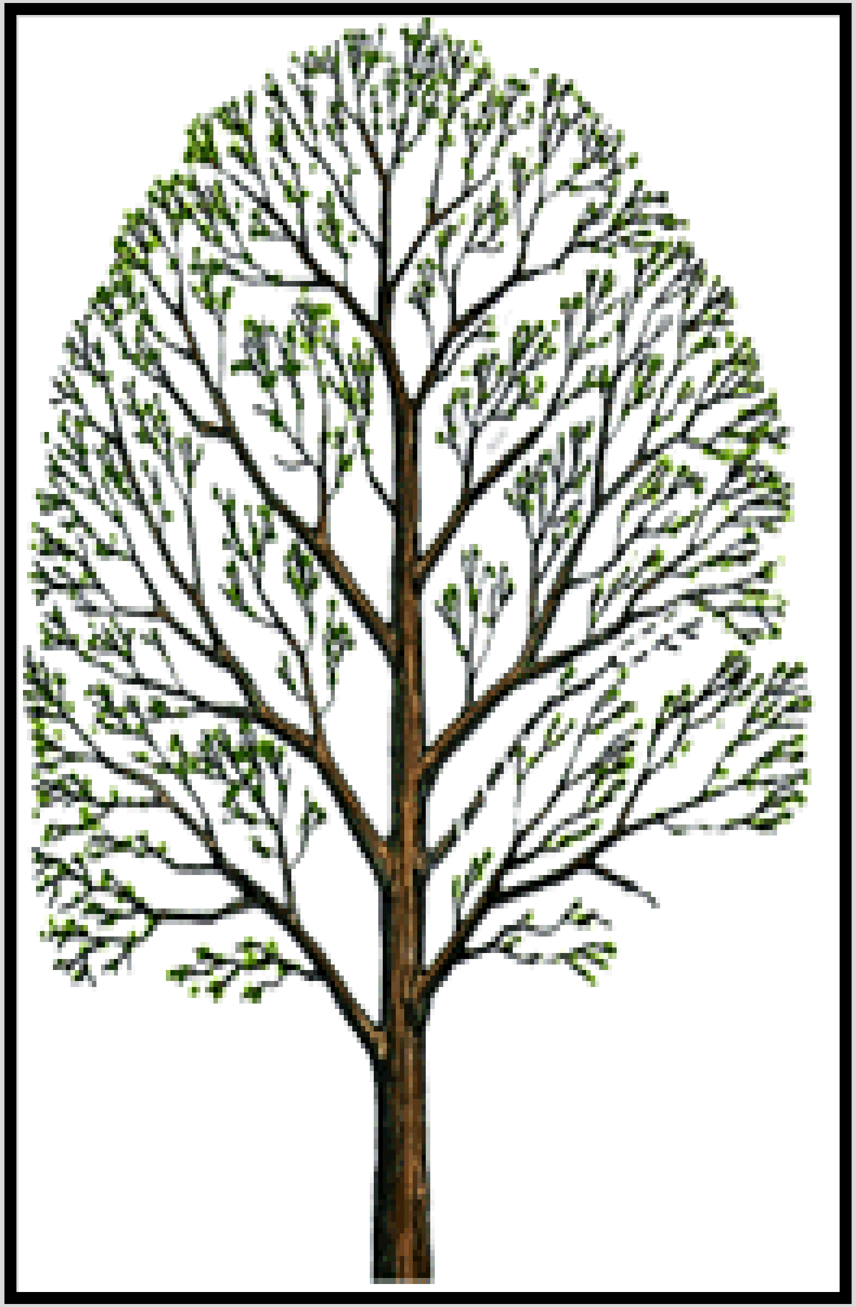
Modified from Trussell and Trussell (2005).
SOURCES: NRC (2004b), Cooley et al. (2006), Sedlak and Pinkston (2001), Heberer et al. (2001),
AWWA (1999), AWWARF et al. (1996), and NRC (1997).

Reverse Osmosis - a Natural Process

- Water is drawn from a low to a high concentration.   Evapo-transpiration creates a suction which draws water up through the root hairs to the leaves.
- In RO systems pressure is applied to the high concentration side of the membrane to induce osmotic flow of clean water to the low concentration side

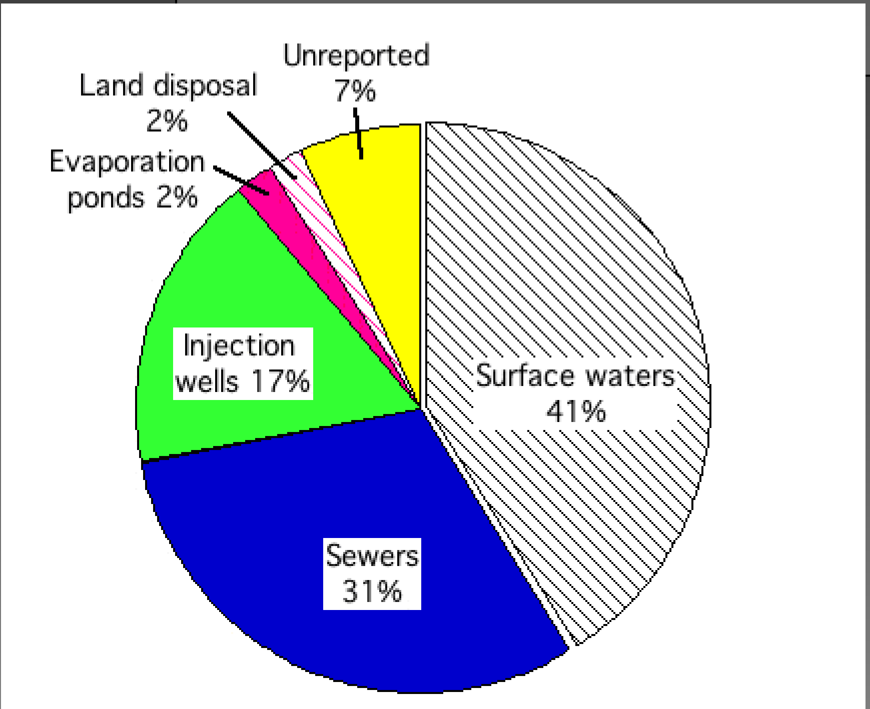
0.1 MGD RO Package System





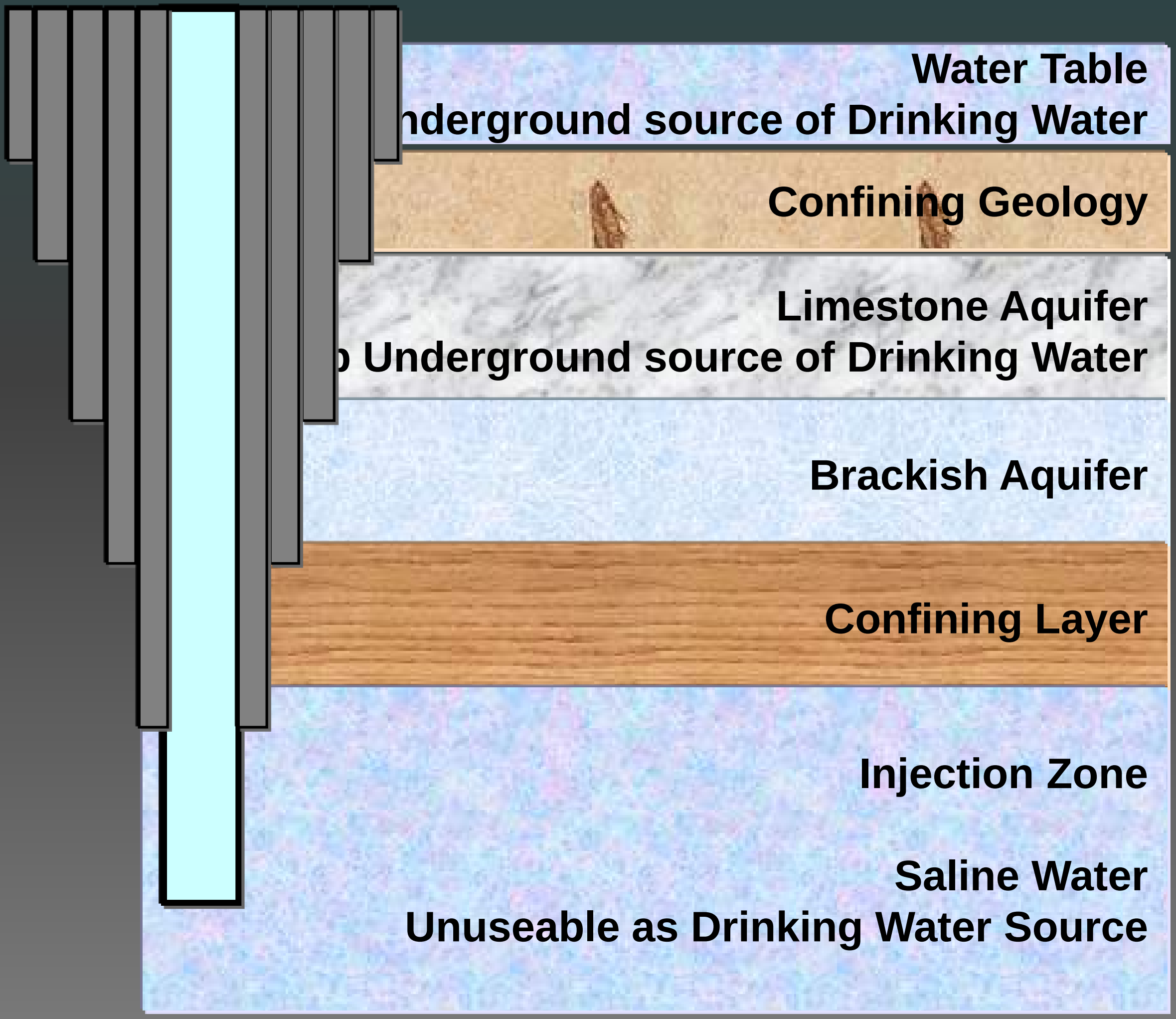
Concentrate Disposal

- Combine with reclaimed water and release to surface water or re-inject.
- Deep Well injection - Limited by Geology
- Evaporation/Crystallization - Capacity limited
- Saline wetlands
- Irrigation – salt tolerant crops (ie golf courses, roadway vegetation) – Soil salt accumulation limited



Identified methods of concentrate management, based on a survey of the 234 municipal desalination plants in the United States with output greater than 95 m3/day (25,000 gallon per day). SOURCE: Mickley (2006).

Deep Well Injection



- Depends on geology
- Requires multiple casing layers to protect aquifers above the injection point

Evaporation/Chrystalization

- ✡ Need high evaporation rate
- ✡ Inexpensive land protected from flooding

Saline Wetlands

Irrigation

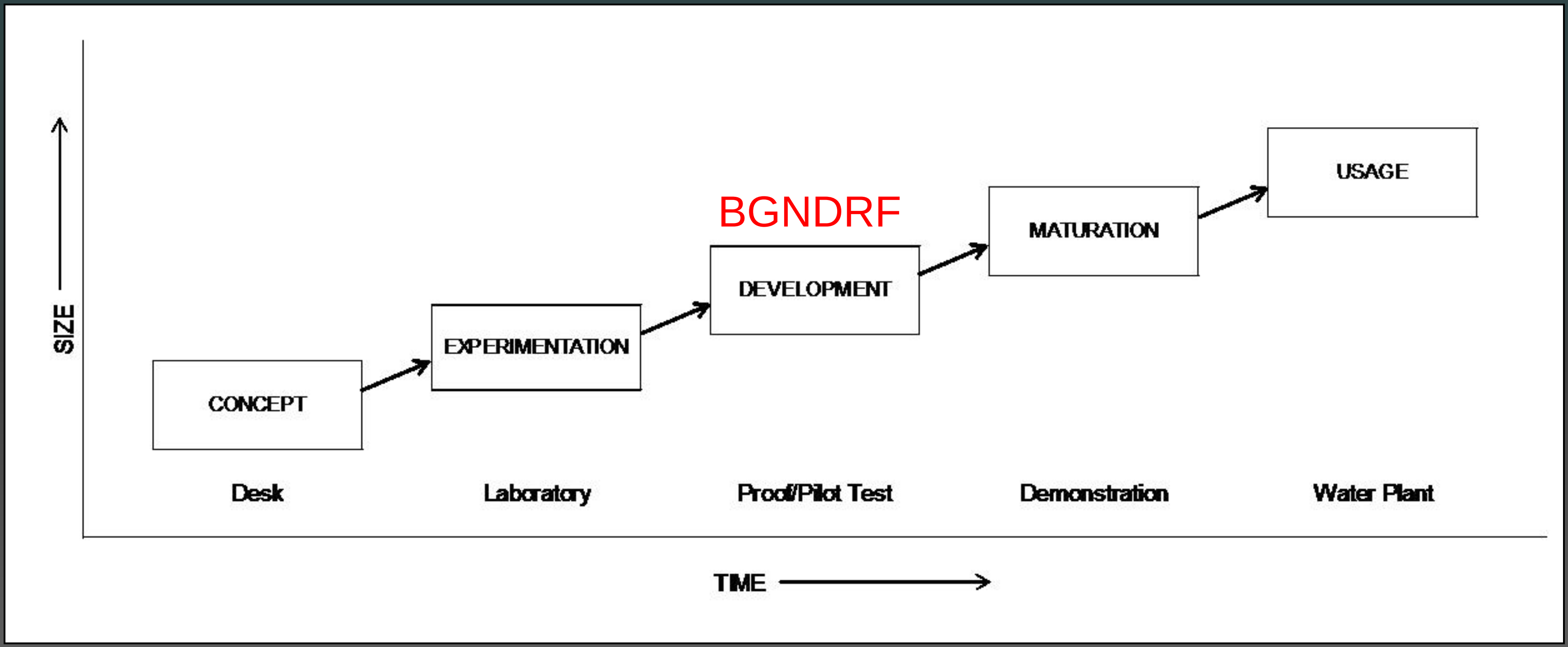
The Brackish Groundwater National Desalination Research Facility (BGNDRF)

Randy Shaw, PE
Facility Manager

What Is It?

- It is a federal research facility, focused on:
  - Concentrate Management
  - Renewable Energy/Desalination Hybrids
  - Produced Water Desalination Technologies
  - Small Scale Systems
  - Public Outreach and Education

Our Niche



SIZE
BGNDRF
USAGE
MATURATION
DEVELOPMENT
EXPERIMENTATION
CONCEPT
Desk
Laboratory
Proof/Pilot Test
Demonstration
Water Plant
TIME

Mission

- Bureau of Reclamation
  – The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

How Did It Happen?

- Discussions with WRRI, Sandia, Congress
- 2001 - Congressional Direction to Plan a Research Facility
  - Sandia National Laboratories and Bureau of Reclamation
- Funding for Planning in FY 2002
- Construction Funding FY 2003 thru FY 2006

Grand Opening 2007

Who Works There?

- Government Agencies
- Universities
- Private Sector

Key Partnership

- Cooperative Agreement
  - IEE; Dr. Abbas Ghassemi
  - WRRI; Dr. Sam Fernald
- Fellowships and Collaborative Research Education Projects
- 5 Master’s Degrees
- Undergraduate Fellows
- 2 PhD Students

Many Collaborations

- CHIWAWA
- ERC ReNUWIt
- Algae/Halophyte Research Collaboration (ASU, U of A, NMSU and Reclamation)
- DESALPOWER
- Reclamation/EPA Community of Practice

The Facility

Past Research

Capacitive Deionization

- Advantages over conventional RO are:
  - Low pumping energy
  - Simple process

- UTEP and Voltea
- Privately Funded
- Brackish Water and Produced Water Testing

High Recovery Reverse Osmosis (RO)

- **Small-scale RO system utilizing a closed system concentrate storage and recirculation approach.**
  - **Uses less energy than conventional RO**
  - **Uses fewer membranes for high recovery**

- **Texas Tech University**
- **Funded by Texas Water Development Board**

Pressure Retarded Osmosis (PRO)

- **RO Combined with Forward Osmosis for Energy Reduction**

- University of Nevada at Reno
- DWPR Grant

Reverse Osmosis (Patented Control)

- Targeting Enhanced Oil Recovery (EOR)
  - Allows producers to customize water quality in real time to optimize EOR performance in field

- Water Standard
- Private Funding
- Pilot testing included RO & NF membrane evaluations

Ongoing Research

- Photo Voltaic RO (NMSU and BOR; 2013)
- Agricultural Use of Concentrate (NMSU)

- Ion Exchange for Turning Concentrate Waste into Marketable Products (Trailblazer Technologies; 2014)
- Radial Deionization (Danlin Industries; 2013)

Questions and Discussion

www.usbr.gov/research/AWT/BGNDRF/index.html

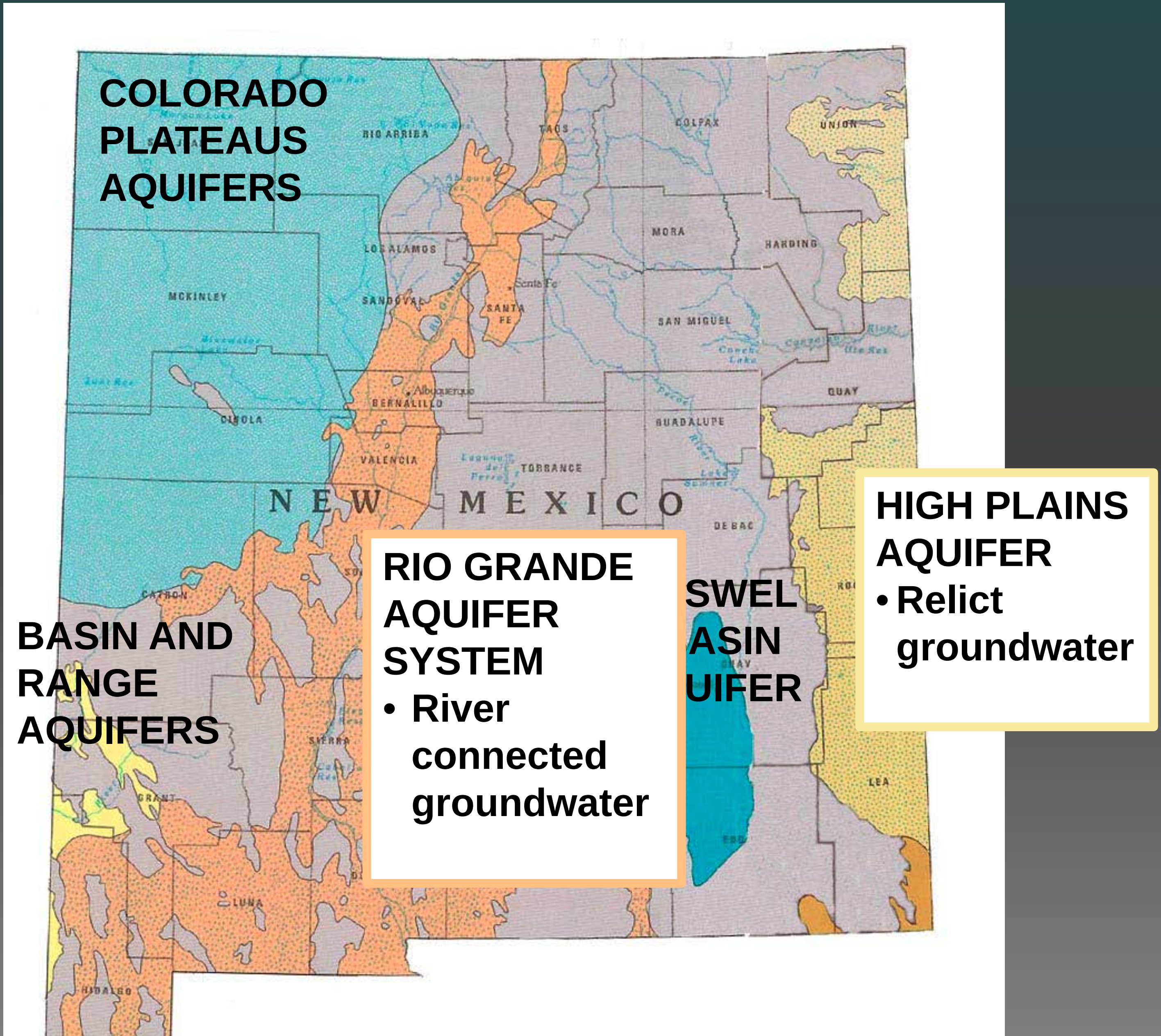
Randy Shaw
Facility Manager
Rshaw@usbr.gov
(575) 443-6553

http://hiddenunseen.blogspot.com/2012/04/top-9-unusual-deserts.html

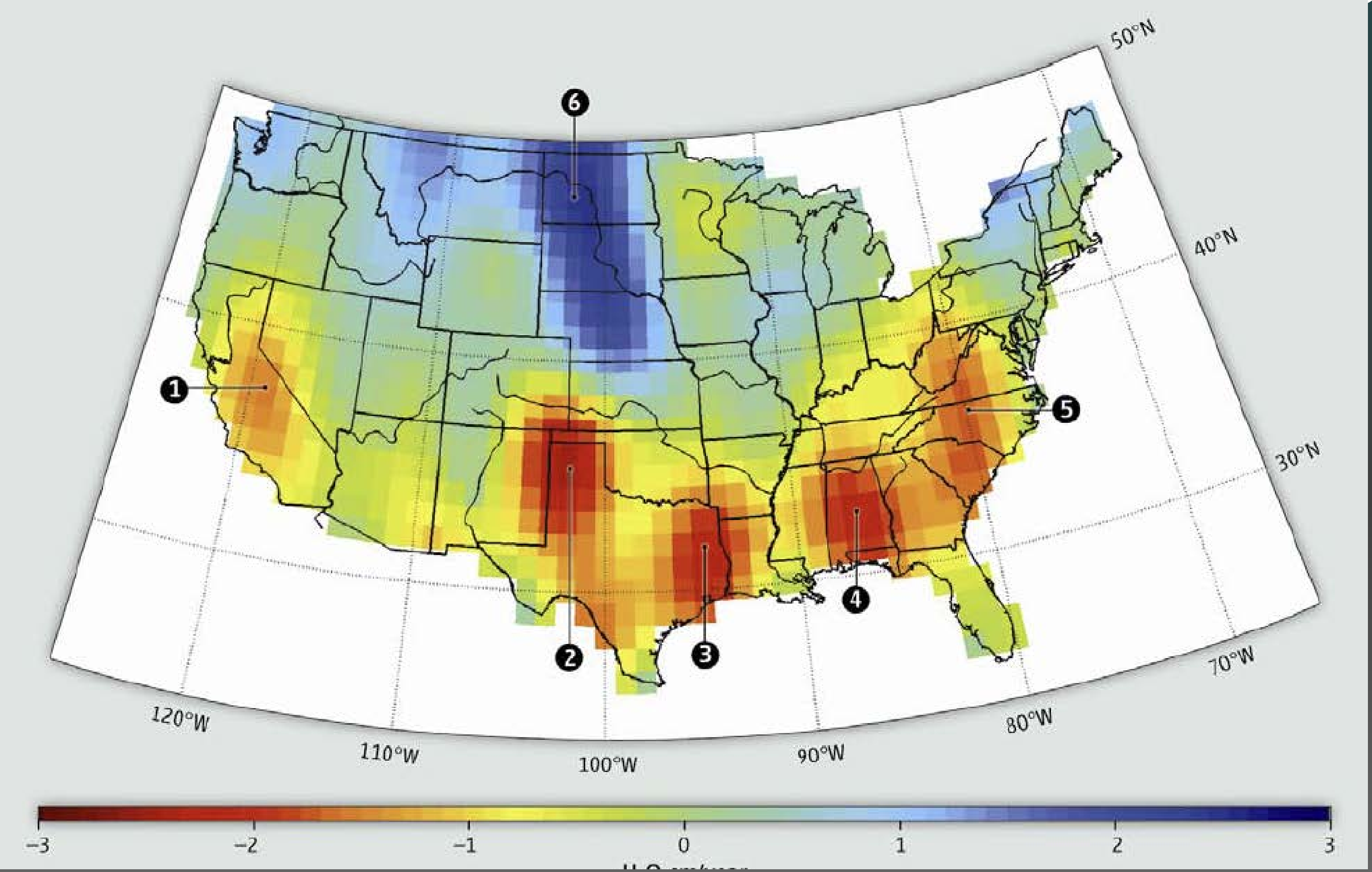
Where to go from here

- Research
- Application

Regions of relict groundwater compared to surface water-connected groundwater



Gravity-based groundwater change



ENVIRONMENTAL SCIENCE

Water in the Balance

James S. Famiglietti[1,2,3] and Matthew Rodell[4]

Satellite data may enable improved management of regional groundwater reserves.

14 JUNE 2013 VOL 340 SCIENCE www.sciencemag.org
Published by AAAS

Updated groundwater assessment

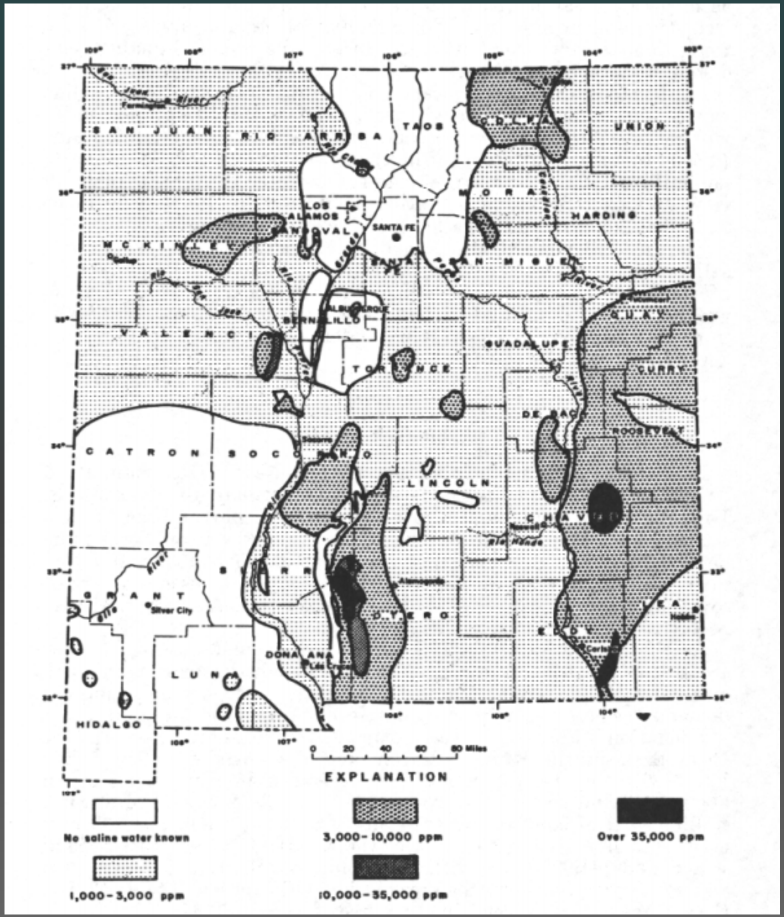
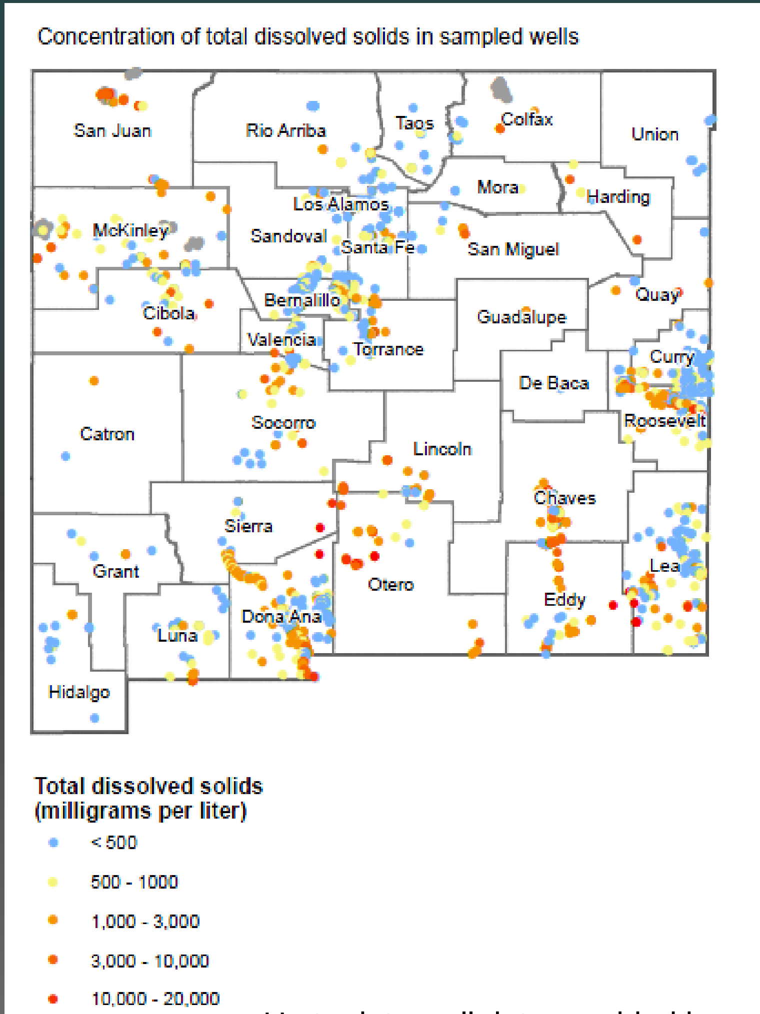


Figure 1. Map of the general occurrence of saline groundwater published by the New Mexico State Engineer and United States Geologic Survey in 1965 with data from an estimated 300 to 500 wells.



Up to date well data provided by EMNRD, EPA, NMED, and USGS

Figure 2. Map from 2012 data showing over 1500 wells with total dissolved solids.

TABLE 2-1. Examples of Variation in Water Quality Used as Source Water for Desalination

Ion (mg/L)	Average Seawater[a]	El Paso Water Utilities, TX Airport Wells[b]	Indian Wells Valley Water District, CA Avg. case*[c]	Sarasota County, FL Well[d]	Colorado River Water near Andrade, CO[e]
TDS	35,000	3,170	1,630	1,180	1,021
Chloride	19,000	1,370	236	27.1	181
Sodium	10,500	745	333	24.6	185
Sulfate	2,700	301	570	609	342
Magnesium	1,350	38.4	49	70.1	38.3
Calcium	410	176	164	166	104
Potassium	390	15.9	6.1	4.02	5.7
Bicarbonate	142	75	370	144	160
Bromide	67	0.05	-	-	-
Strontium	8	-	1.55	-	1.4
Silica	6.4	29.4	45	-	14.2
Boron	4.5	-	1.74	-	-
Fluoride	1.3	0.61	1	-	0.5
Nitrate	3.0	0.11	72	-	2.6
Arsenic	0.003	-	0.0052	-	0.0035
Uranium	0.003	-	0.080	-	0.0038
Selenium	0.00009	-	0.059	-	0.0023

* Equal blend of four wells.
\- No data.

Desalination technologies

One size does not fit all

TABLE 4-3 Comparison of Predominant Brackish Water Desalination Processes

	Brackish water RO	**ED/EDR**	**NF**
Operating temperature (°C)	<45	<43	<45
Pretreatment requirement	High	Medium	High
Electrical energy use (kWh/m^3)	0.5-3	~0.5 kWh/m^3 per 1,000 mg/L of ionic species removed	<1
Current, typical single train capacity (m^3/d)	< 20,000	<12,000	<20,000
Percent ion removal	99-99.5%	50-95%	50-98% removal of divalent ions; 20-75% removal of monovalent ions
Water recovery	50-90%	50-90%	50-90%

SOURCES: Anne et al. (2001), Wangnick (2002), Kiernan and von Guttberg (2005), Reahl (2006), Sethi et al. (2006b), USBR (2003).

Priority Research Areas

1. Understand the environmental impacts of desalination and develop approaches to minimize these impacts relative to other water supply alternatives

b. Conduct field studies to assess environmental impacts of brackish groundwater development**

c. Develop protocols and conduct field studies to assess the impacts of concentrate management approaches in inland and coastal settings**

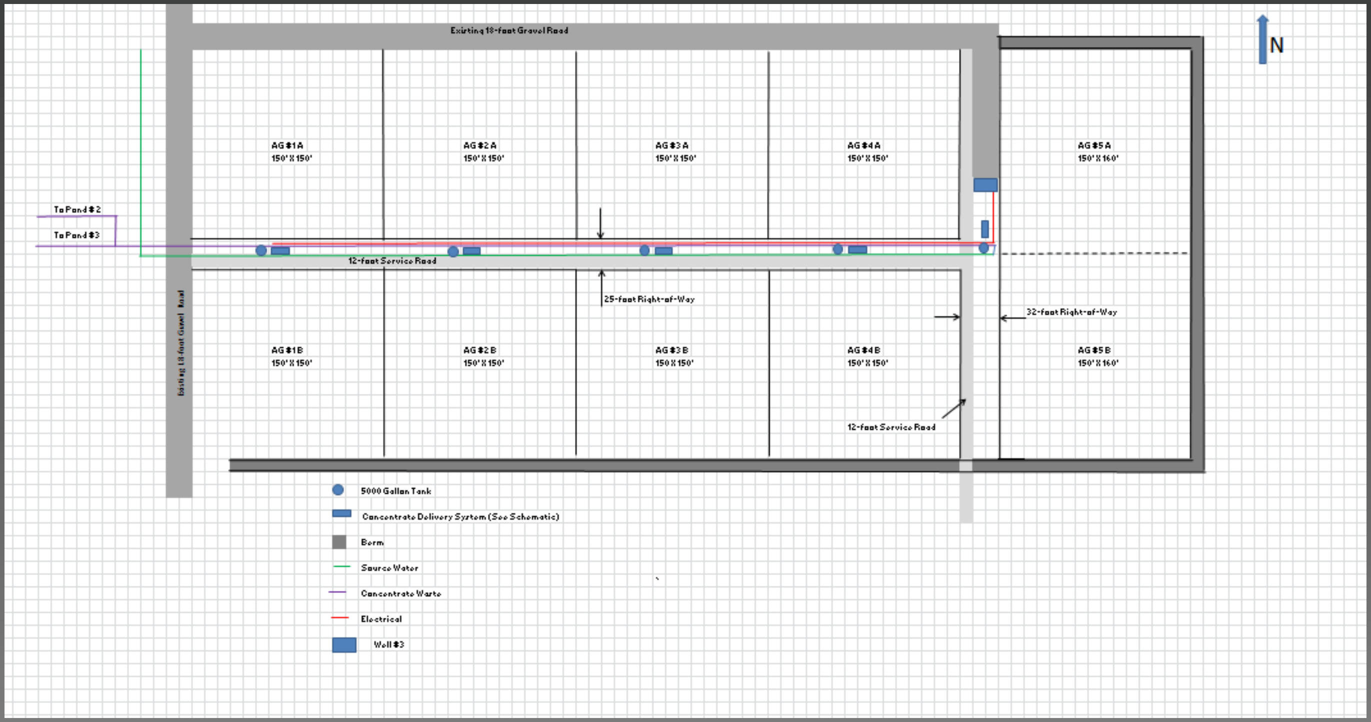
2. Develop approaches to lower the financial costs of desalination so that it is an attractive option relative to other alternatives in locations where traditional sources of water are inadequate.

a. Improve pretreatment for membrane desalination
b. Improve membrane system performance
c. Improve existing desalination approaches to reduce primary energy use
d. Develop novel approaches and/or processes to desalinate water in a way that reduces primaryenergy use**

3. Develop cost-effective approaches for concentrate management that minimize potential environmental impacts

Agricultural water use of concentrate

Tier 1 – Identify suitable crops in greenhouse
Level 2 – Test at BGNDRF
Sustainable agriculture
Profitable crop
Regional – Water budget implications



Santa Teresa Border Initiatives – Policy and application example

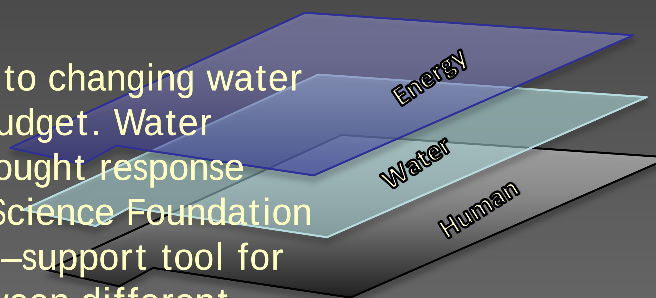
Economic growth along the U.S.-Mexican border depends on a reliable water supply. Published NMWRRI research as well as ongoing cooperative transboundary studies on the binational Mesilla Basin aquifer system indicates that large quantities of low-salinity groundwater are stored beneath the more-limited freshwater aquifers of the West Mesa area west of the Rio Grande's Mesilla Valley. A conservative estimate of the economically recoverable reserve of fresh and slightly brackish groundwater is about 50 million acre-feet. This is an untapped resource with a potential for desalination at a scale of or exceeding that currently being developed by El Paso Water Utilities. NM WRRI can coordinate an effort to extend the estimated 10 years of fresh water supply to 100 years of combined fresh and treated brackish water. This project will bring together water supply and water quality assessment with desalination water treatment for sustainable border communties.

DESALINATION SUPPORTED BY NM WRRI MISSION AND FUNDING PRIORITIES

#1. FY15 NM WRRI Expansion Request $350,000/year

The NMSU Board of Regents has given #1 priority status to the NM WRRI legislative request for $350K in additional yearly funding to support water research. NM WRRI has the proven ability to coordinate efforts statewide, and this funding would support research in critical areas such as policy, drought, water scarcity, water quality and water treatment issues. If passed, this appropriation to NM WRRI will help fix water resource problems through support of scientists, faculty, and students.

***Statewide Water Budget* -** To improve New Mexico's ability to respond to changing water conditions, NM WRRI is beginning work on a statewide dynamic water budget. Water availability and use by region relies on up to 10-year old data, when drought response needs to occur on a yearly time frame. Seed money from the National Science Foundation will be used to develop the water use assessment that drives a decision–support tool for energy development in New Mexico, showing trade-offs that occur between different energy and economic development choices while maintaining sustainable water use. Future funding will coordinate the statewide water budget with water management agencies and will make the resource available to researchers and stakeholders to support cutting-edge multidisciplinary water research interacting with all sectors of the economy and the environment.



New Mexico is a great place for desal.

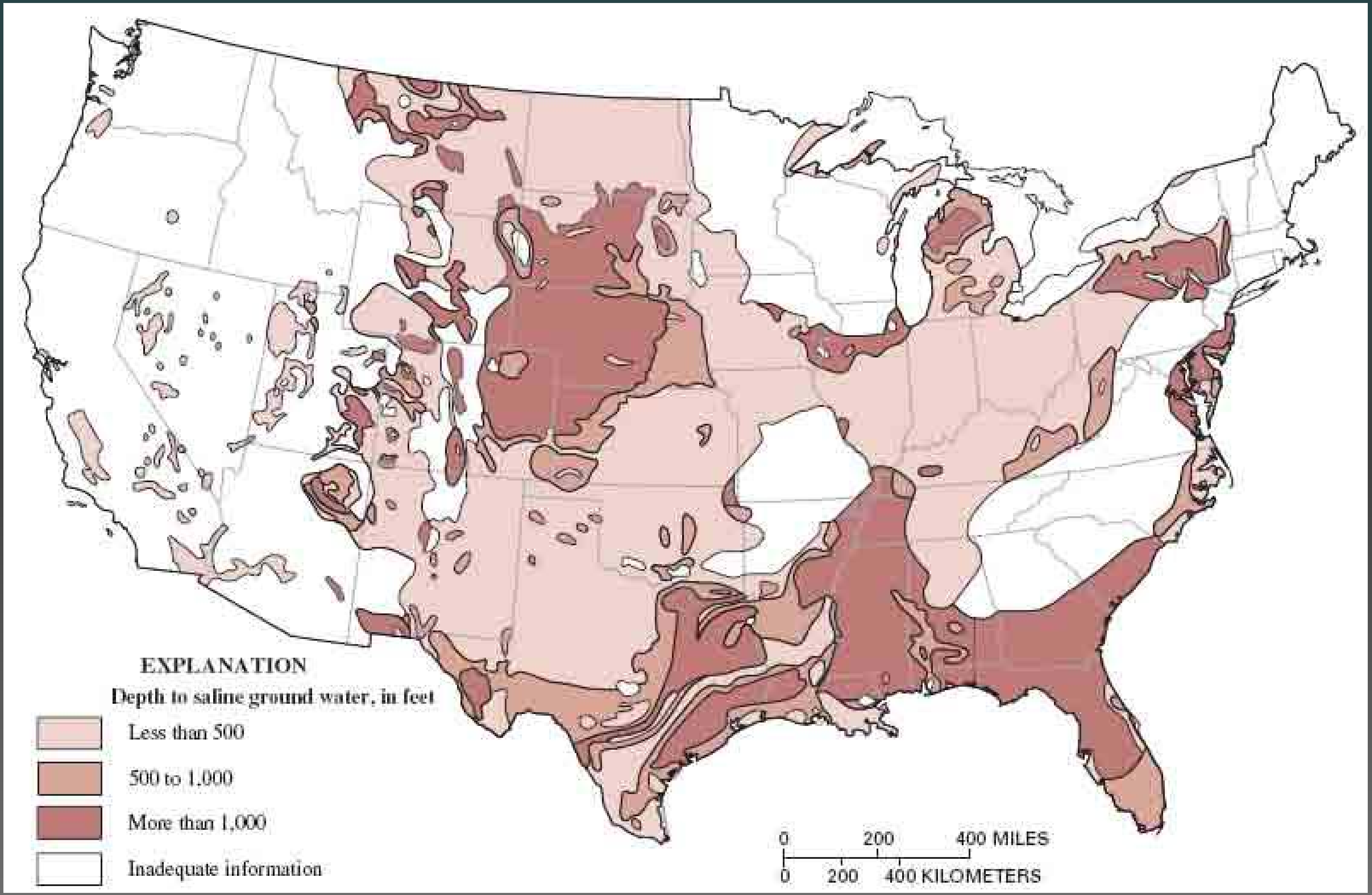
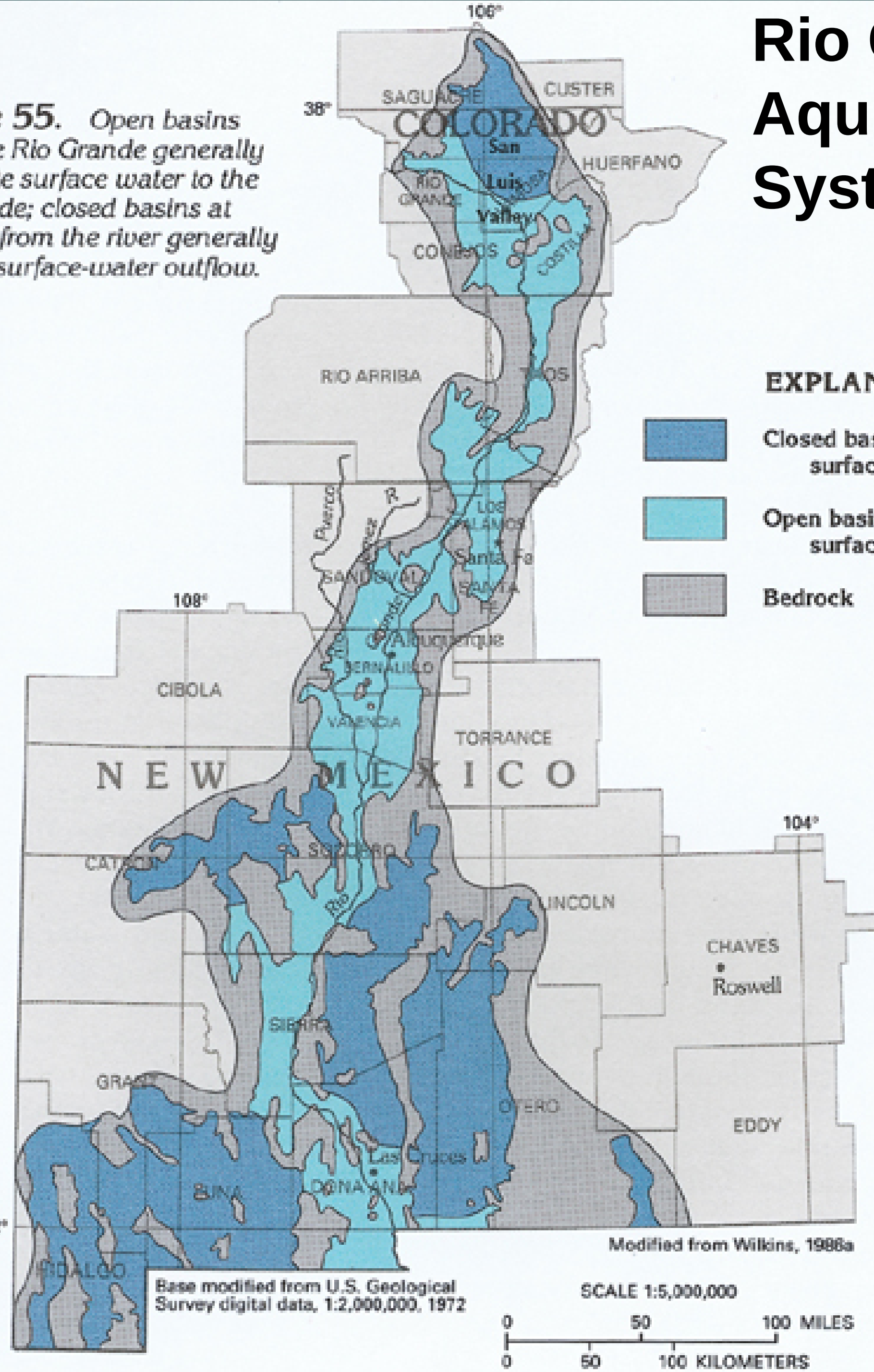


FIGURE 1-1. Depth to brackish groundwater (greater than 1,000 mg/L total dissolved solids) in the conterminous United States (generalized from Feth, 1965).

Rio Grande Aquifer System

Figure 55. Open basins along the Rio Grande generally contribute surface water to the Rio Grande; closed basins at distance from the river generally have no surface-water outflow.



EXPLANATION

- Closed basins that have internal surface-water drainage
- Open basins that can contribute surface water to the Rio Grande
- Bedrock

GROUND WATER ATLAS of the UNITED STATES
Arizona, Colorado, New Mexico, Utah
HA 730-C

Membranes

	ED	MF	UF	NF	RO
Retained	Water, TSS, microbes uncharged molecules	Larger particles	Larger molecules	Higher charged ions	Most everything
Transported	Dissolved salts	Water, dissolved salts, small particles	Water, small molecules and ions	Water, Mono-valent ions, small molecules	Water, very small uncharged molecules
Productivity (gfd)	Practically None	20-100k	10-20	25	20

Desalination: A National Perspective - National Academy of Science 2008

COSTS AND BENEFITS OF DESALINATION

There have been significant reductions in membrane costs and improvements in the energy efficiency of the desalination process. Perhaps more significant, the costs of other alternatives for augmenting water supplies have continued to rise, making desalination production costs moreattractive in a relative sense.

Nevertheless, the costs of concentrate management are potentially large and vary from site to site. Such costs have the potential to offset reductions in water production costs.

opportunities exist to further reduce cost and energy use of current technologies by small but economically significant amounts **In RO desalination, the costs and energy requirements of water production can be further reduced by mitigating fouling through pretreatment; developing highpermeability, fouling-resistant, high-rejection, oxidant-resistant membranes; and optimizing membrane module and membrane system design.**

Few, if any, cost-effective environmentally sustainable concentrate management options exist for inland desalination facilities. Several methods are currently available for concentrate management, and each method has its own set of site-specific costs, benefits, regulatory requirements, environmental impacts, and limitations. Low- to moderate-cost inland disposal options can be limited by the salinity of the concentrate and by location and climate factors. Only evaporation ponds and high-recovery/thermal evaporation systems are zero-liquid discharge solutions, but high costs limit their consideration for most municipal applications.

Monitoring and assessment protocols should be developed for evaluating the potential ecological impacts of surface water concentrate discharge. Adequate sitespecific studies on potential biological or ecological effects are necessary prior to the development of desalination facilities, and planners would benefit from clear guidance on appropriate monitoring and assessment protocols.

There are small but significant efficiencies that can be made in membrane technologies that will reduce the energy needed to desalinate water and, therefore, offer potentially important process cost reductions. Development of membranes that operate effectively at lower pressures could lead to 5 to 10 percent reductions in total costs of the desalination process associated with a 15 percent decrease in energy use**. In** contrast, extending membrane life beyond the current 5-year design life is likely to have a small impact on desalination costs because membranes account for a minimal proportion of total costs. Prevention of catastrophic failure through robust pretreatment is important because membrane failure within the first year of operation can cause an annual cost increase of more than 25 percent.