Desalination in Texas
What’s Next?

April 9, 2004
Spring 2004 BEG Technical Seminar Series

Jean-Philippe Nicot, P.E.
Bureau of Economic Geology
The University of Texas at Austin
The Quote

“…..And we must not only improve water conservation, but desalinate the saltwater that splash upon our coast each day.”

Governor Rick Perry
State of the State Address
February 11, 2003
Presentation Outline

• Introduction:
  – Some Numbers
  – Legislative Environment
• Why the Fuss over Desalination?
• The Technologies
  – Membrane-based Technologies
  – Distillation-based Technologies
• Concentrate Disposal
• The Future
Some Numbers, World

- ~12,000 desalination plants in the world, producing >6,000 MGD (<1% of total consumption). More than half of them are in the Middle East and North Africa. ~25% of production in Saudi Arabia.

Source: ABC of Desalination, O.K. Buros, 2000
Some Numbers, U.S.

- ~800 desalination plants in the US, with a capacity of ~225 MGD (>1% of US consumption of 16,000 MGD), most of them in Florida, California, and Texas.

Source: Mickley & Associates
NUMBER OF DESALTING PLANTS BY STATE
(through 2002)

Plants >0.25 MGD

Source: Mickley & Associates
Some Numbers, Texas

- ~100 desalination plants in Texas with a capacity of ~40-50 MGD
Current Desalination Plants in Texas

Desalination Plant Production
(Millions of gallons per day)

- 0 - 1
- 1 - 4
- 4 - 7
- 7 - 10
- 10 – 27

Ground Water
Surface Water
Cities

Note: production numbers may include blending of the desalted stream with other water.
There are incentives for desalination research and demonstration projects at the federal and state levels:

**Water Desalination Act (1996):**
- authorizes the Secretary of the Department of the Interior to award grants and contracts for desalination research, development ($5M/yr) and demonstration projects ($25M/yr)
- Managed by the Bureau of Reclamations
- Amended in 2001 (Water Supply Security Act) by creating a research facility at Tularosa, NM and increasing grants to $6M/yr and $30M/yr through 2008
• 77th Texas Legislature: SB2
  – Addresses implementation and financing of the water strategies and recommendations identified in the last four years by Texas' 16 regional water planning groups (SB1 of 75th)
  – encourages investments, provides for grants for projects from the Water Loan Assistance Fund, allows taxing units to exempt property approved for desalination projects from property taxes, and exempts equipment, services, and supplies used for desalination projects from the state sales tax
Legislative Environment

• 78th Texas Legislature: HB1370
  – Requires the TWDB to address desalination needs
  – “The board shall undertake or participate in research, feasibility planning studies, investigations and surveys as it considers necessary to further the development of cost-effective water supplies from sea water desalination in the state.”
  – “The board shall prepare a biennial progress report (next due December 1st 2004)”
Regions with Desalination Water Management Strategies

Source: Water for Texas, TWDB, 2002
Plants on the Horizon

- TWDB appropriated $1.5M for feasibility studies (Port of Brownsville, Corpus Christi, Freeport)
- Corpus Christi / Northern Padre Island
- El Paso / Ft. Bliss
- Wichita Falls, Abilene, San Antonio
WHY DESALINATION?
The Problem

• Texas population will likely grow from 21M in 2000 to 40M in 2050
• Despite conservation measures, demand for water will grow from 17M AFY in 2000 to 20M AFY in 2050
• Municipal water needs will increase from 4.2M AFY in 2000 to 7.1M AFY in 2050

1 AF = 43,650 cft = 325,851 gal
1 M AFY = 892 MGD

Source: Water for Texas, TWDB, 2002
Water Use by Category

Source: Water for Texas, TWDB, 2002
Per Capita Water Use (year 2000)

Source: Water for Texas, TWDB, 2002
Counties with Unmet Needs in 2050

Source: Water for Texas, TWDB, 2002
A Solution: Desalination

- Desalination of brackish water / sea water is a drought-proof, mature technology
- Current desalination municipal capacity is ~0.045 M AFY (~1% of demand), this produces a waste stream of ~5-10 M gal/day (to be compared to the more than 600 M gal/day of produced waters in Texas – 2/3 in the Permian Basin)
- Unconventional water sources are already considered and/or used (reuse of waste water, brackish water, sea water, produced waters) in addition to conservation and additional development of conventional sources (surface and ground water)
THE TECHNOLOGY
Available Technologies

• Membrane-based Technologies
  – Reverse Osmosis (RO)
  – Electrodialysis (ED) and ED Reversal (EDR)
  – [Low pressure membrane technologies = UF, MF]

• Distillation Technologies
  – Multi-stage flash distillation (MSF)
  – Multiple effect distillation (MED)
  – Vapor compression distillation (VC)

• Alternative Technologies
  – Freezing
  – Membrane distillation
  – Solar humidification

World desalination capacity by process
Reverse Osmosis (RO)

Source: AWWA

2 MGD Oceanside, CA RO Installation
Membrane-Based Technologies

- Microfiltration (MF): 10-0.1µm - bacteria, suspended solids
- Ultrafiltration (UF): 0.05-0.005µm - colloids, volatile organics, macromolecules, virus (and color&odor)
- Nanofiltration (NF): 5-0.5nm – sugars, dyes, divalent salts; water softening, sulfate removal
- Reverse Osmosis (RO): 0.5-0.05nm – monovalent salts, ionic salts
- Electrodialysis (ED) and electrodialysis reversal (EDR)
Electrodialysis Reversal (EDR)

Before polarity reversal:
- Cathode (-)
- Anode (+)
- Cation Exchange Membrane
- Anion Exchange Membrane
- Concentrate
- Demineralized

After polarity reversal:
- Anode (+)
- Cathode (-)
- Cation Exchange Membrane
- Anion Exchange Membrane
- Concentrate
- Demineralized

Source: AWWA

12 MGD Sarasota, FL EDR plant
Multi-Stage Flash Distillation (MSF)

Source: ABC of Desalination, O.K. Buros, 2000
# Process Characteristics

<table>
<thead>
<tr>
<th></th>
<th>RO</th>
<th>EDR</th>
<th>MSF/MED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred Water Source</td>
<td>Any</td>
<td>Brackish</td>
<td>Seawater - Brine</td>
</tr>
<tr>
<td>Susceptibility to scaling</td>
<td>high</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Bacterial Contamination</td>
<td>Possible</td>
<td>Post-treatment always needed</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Final Product Salinity</td>
<td>On demand (&lt;500 mg/L TDS)</td>
<td>On demand (&lt;500 mg/L TDS)</td>
<td>Can be &lt;10 mg/l TDS</td>
</tr>
<tr>
<td>Energy Cost</td>
<td>Moderate, increases with salinity</td>
<td>High, increases fast with salinity</td>
<td>High, independent of salinity</td>
</tr>
<tr>
<td>Recovery</td>
<td>Typically 50% for seawater, &gt;80% for brackish water</td>
<td>&gt;80% for brackish water</td>
<td>Poor= 10-25%</td>
</tr>
<tr>
<td>Plant Size</td>
<td>Modular, easy to operate, small footprint</td>
<td>Modular, easy to operate, small footprint</td>
<td>Large complex plants</td>
</tr>
</tbody>
</table>
Raw Water Sources

- Sea water from ocean or from shallow beach wells
- Brackish water (surface or aquifer)
- Waste water
- Oilfield produced waters
Brackish Waters: El Paso Area

Source: LBJ Guyton, 2003
Brackish Water Distribution

- Abundant resource throughout the state often at shallow depths with reasonable well yield

Source: LBJ Guyton, 2003
Produced Waters

- Texas A&M developing specific technology to treat produced waters
- Could be used for irrigation and cattle
- Proximity of the water resource to the place of use

Source: Dave Burnett, 2004
Pre-treatment

• Pre-treatment is an important step of RO and could be a significant fraction of total cost:
  – Removal of particulates: MF
  – Removal of colloids to limit membrane fouling: chemical coagulation (alum, activated silica) or UF
  – Scaling issues: lime addition, softening (NF or ion exchange) to remove Ca/Mg, acidification to regulate pH
### Is Desalination Cost-Effective?

<table>
<thead>
<tr>
<th>Plant Location</th>
<th>Capacity (MGD)</th>
<th>Cost (/1,000 gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinidad</td>
<td>26</td>
<td>$2.67</td>
</tr>
<tr>
<td>Askelon (Israel)</td>
<td>2X37</td>
<td>$1.99</td>
</tr>
<tr>
<td>Tampa Bay, FL</td>
<td>25</td>
<td>$1.70</td>
</tr>
<tr>
<td>Singapore</td>
<td>36</td>
<td>$1.60</td>
</tr>
<tr>
<td>Southmost RWA</td>
<td>7.5</td>
<td>~$1.50</td>
</tr>
</tbody>
</table>

- **Austin, TX**
  - $0.8/1,000 gal (<2,000 gal)
  - $2.3/1,000 gal (>2,000 gal)

Source: Jorge Arroyo, TWDB
Notes on Cost

• RO pressure requirement for brackish water is much less than that for seawater, desalination of brackish water is less expensive than desalination of sea water.

• EDR is currently cost-effective only for low salinity sources

• Distillation-based technology cost is not function of salinity, they make sense only for higher salinity sources (seawater)
Cost Trends

Cost per 1,000 gallons including debt service and operations

Source: Southmost RWA
CONCENTRATE DISPOSAL
Concentrate Disposal Options

• Fate of concentrate is the biggest issue facing desalination:
  – Ocean: typically several miles offshore with diffusers (dilution)
  – Surface water, sewer, land application (dilution)
  – Evaporation pond
  – Deep well injection
  – Zero-discharge=Industrial re-use: chemical/plastic industry, beneficial use
### Concentrate Disposal

<table>
<thead>
<tr>
<th>Method</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sewer</td>
<td>X</td>
<td>X</td>
<td>---</td>
</tr>
<tr>
<td>Deep-Well Injection</td>
<td>---</td>
<td>(X)</td>
<td>X</td>
</tr>
<tr>
<td>Land</td>
<td>X</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Evaporation Pond</td>
<td>X</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Source: Mickley & Associates
Deep-Well Injection in Texas

- Geology is very favorable for deep-well injection
- There is a long history of injecting both waste and produced waters
- Current desalination waste stream accounts for less than 1 percent of state-wide produced water volume.
- There is no technical difficulty in injecting desalination waste along with produced waters
Deep-Well Injection in Texas

• Regulated by Clean Water Act, Underground Injection Control, and state and local regulations (Title 30 of TAC)

• Class I Injection well applications are expensive and technically complex, but this is currently the only class allowed to accept desalination wastes

• Injection along with produced waters into Class II wells for pressure maintenance or for EOR could greatly simplify the process to the benefit of both desalination and oilfield operators
Surface Discharge

• Convenient from sea water plants with high volume of concentrate
• Inland surface water body and evaporation pond discharge requires permitting by state and local regulations (Title 30) and must observe Clean Water Act regulations
Zero Discharge

- Maximize water recovery
- May improve public acceptance
- Can have high operational and investment costs: need to evaporate brine to dry products
- Cost can be offset by beneficial use of by-products (brine or specific salts)

Source: Geo-processors Limited PTY, AU
Precipitated Calcium Carbonate (PCC)
# Other Disposal Issues

<table>
<thead>
<tr>
<th></th>
<th>Is Increased Recovery Better?</th>
<th>Compatibility Issues</th>
<th>Future Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water</td>
<td>no</td>
<td>yes</td>
<td>yes*/no</td>
</tr>
<tr>
<td>Sewer</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Deep-Well Injection</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Land</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Evaporation Pond</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Zero-discharge</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

* ocean

Source: Mickley & Associates
THE FUTURE
Favorable Conditions

• We are entering an era where water is treated as a commodity
• Texas water laws give power to local governments (Groundwater Conservation Districts, municipalities) to manage water issues facilitating agreements with, for example, local oil operators
Future Trends and Potential Challenges

- As the number of plants grows, regulations will become more numerous and more stringent
- Environmental concern will increase, public outreach will be of utmost importance
- Source water quality will deteriorate
- Increase need for pretreatment
- Disposal cost will become an increasing percentage of total costs

Source: Mickley & Associates
Research Directions

• Need to understand the resource, i.e. brackish water distribution
• Membrane efficiency: larger surface area, smaller pressure drop
• Zero-discharge plant
• Net zero-energy plant