Recovery & Concentrate Management

A Quick Look at Three Local Projects

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Vice President, Water Supply & Reuse
How do we make use of what we have available to us?

1. Brackish Groundwater (Buckeye Sink)
2. Sea water (Sea of Cortez)
3. Reclaimed Water (SROG)
Groundwater Project

BRACKISH GROUNDWATER TREATMENT AND BRINE DISPOSAL STUDY
Brackish Groundwater Treatment and Brine Disposal Study

1. Client: Central Arizona Project

2. Scope: Evaluate options for augmenting water supplies using treatment and delivery of brackish groundwater
   a. Treatment technology
   b. Stakeholder value assessment
   c. Brine management options
   d. Conceptual design
   e. Alternatives prioritization
   f. Report

3. Completed: December 2009
Study Area

Stakeholders Included:
Goodyear, Buckeye, Buckeye WCDD, GRIC, and CAWCD
## Raw Water Quality & Finished Water Quality Goals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Raw Groundwater Quality</th>
<th>Finished Water Quality Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>26</td>
<td>—</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>mg/L as CaCO₃</td>
<td>297</td>
<td>—</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>mg/L as CaCO₃</td>
<td>805</td>
<td>—</td>
</tr>
<tr>
<td>Calcium Hardness</td>
<td>mg/L as CaCO₃</td>
<td>470</td>
<td>—</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>mg/L</td>
<td>2,283</td>
<td>500 – 1,000⁽¹⁾</td>
</tr>
<tr>
<td>pH</td>
<td>Standard pH unit</td>
<td>—</td>
<td>7 to 8.5</td>
</tr>
<tr>
<td>Calcium Carbonate Precipitation Potential (CCPP)</td>
<td>mg/L as CaCO₃</td>
<td>—</td>
<td>4 to 10</td>
</tr>
<tr>
<td>Primary MCLs</td>
<td>—</td>
<td>—</td>
<td>Not exceeded</td>
</tr>
</tbody>
</table>

1. Range of TDS goals were considered: 500, 700, 800, and 1,000
Preliminary Concentrate Management Alternatives

1. Cooling Water
2. VSEP $\rightarrow$ Thermal Brine Concentrator $\rightarrow$ Crystallizer
3. Chemical Precipitation (w/ Secondary RO) $\rightarrow$ Thermal Brine Concentrator $\rightarrow$ Crystallizer
4. Chemical Precipitation (w/ Secondary RO) $\rightarrow$ Thermal Brine Concentrator $\rightarrow$ Evaporation Pond
5. VSEP $\rightarrow$ Thermal Brine Concentrator $\rightarrow$ Evaporation Pond
6. Chemical Precipitation (w/ Secondary RO) $\rightarrow$ Evaporation Pond
7. VSEP $\rightarrow$ Evaporation Pond
Comparison of Stakeholder Values for Brine Mgmt Alternatives

<table>
<thead>
<tr>
<th>Brine Management Option</th>
<th>Cost Rank</th>
<th>Groundwater Resource Conservation Rank</th>
<th>Sustainability</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Water Supply</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>Least chemicals, labor and power</td>
</tr>
<tr>
<td>CP → EP</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>More chemicals, labor and power required for CP &amp; secondary RO.</td>
</tr>
<tr>
<td>CP → BC → EP</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>More chemicals, labor and power required for BC</td>
</tr>
<tr>
<td>CP → BC → CRYS</td>
<td>3</td>
<td>1 (tie)</td>
<td>6</td>
<td>Most chemicals required for BC &amp; CRYS.</td>
</tr>
<tr>
<td>VSEP → EP</td>
<td>7</td>
<td>6</td>
<td>2</td>
<td>More chemicals, labor and power required VSEP.</td>
</tr>
<tr>
<td>VSEP → BC → EP</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>More chemicals, labor and power required for BC</td>
</tr>
<tr>
<td>VSEP → BC → CRYS</td>
<td>5</td>
<td>1 (tie)</td>
<td>7</td>
<td>Most labor and power required for VSEP, BC &amp; CRYS.</td>
</tr>
</tbody>
</table>

Notes:
(1) Based upon 2nd year annual costs presented in Table 2.10 (and also in Appendix C).
(2) Rank of 1 = Most Favorable; Rank of 7 = Least Favorable
(3) Recovery rates based upon flows presented previously in Tables 2.3 through 2.9 (and also in Appendix B)
(4) Accounts only for groundwater recovery through desalination plant. Brine use as cooling water at the PVNPP not factored into recovery calculation.
The Basic Concept with 2 Brine Management Options

**Option 1**
Cooling water supply to the APS PVNPP.

**Option 2**
Near-ZLD with evaporation ponds.

Diagram showing the flow of water and brine management options within the CAP Desalination Facility Boundary.
Brackish Groundwater Cost & Energy Summary

<table>
<thead>
<tr>
<th></th>
<th>Total Annual Cost - $/AF (Capital &amp; O&amp;M)</th>
<th>Total Annual Power Requirement – kWh/AF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80% recovery</td>
<td>85% recovery</td>
</tr>
<tr>
<td>OPTION 1</td>
<td>$498</td>
<td>$503</td>
</tr>
<tr>
<td>OPTION 2</td>
<td>$1,705</td>
<td>$1,836</td>
</tr>
</tbody>
</table>

- For Option 1, what cost sharing would APS require?
- How big would well field need to be for 26.8 MGD?
- How long & big would pipeline need to be?
- What would property costs be, and where would facilities be located?

**OPTION 1**
Cooling water supply to the APS PVNPP.

**OPTION 2**
Near-ZLD with evaporation ponds.
Sea Water Project

INVESTIGATION OF BINATIONAL DESALINATION FOR THE BENEFIT OF ARIZONA AND SONORA
Investigation of Binational Desalination for the Benefit of Arizona and Sonora

1. Client: Central Arizona Project & Salt River Project
2. Scope: Provide conceptual-level information and opinion of cost data of desalinating Sea of Cortez water for the benefit of Arizona, Sonora, and possibly other users of Colorado River.
3. Completed: June 2009
Study Team

Funding Partners

Cooperating Partner

Agency Partners
Conceptual Treatment Plant

Ocean

Land

Backwash & Concentrate Discharge Diffuser

Clearwell

Post Treatment

High Pressure RO Membranes (45% water recovery)

High Pressure Feed Pumps

High Pressure Membrane Feed Tank

Energy Recovery from Concentrate

Low Pressure Membrane Backwash

Low Pressure Membrane Backwash Pumps

Strainers

Raw Water Pumps

Low Pressure Membrane Feed Tank

Low Pressure Membrane Pretreatment (95% water recovery)

Low Pressure Feed Pumps

Raw Water Intake
Desalinate Sea of Cortez Water & Convey to Imperial Dam
## Arizona-Sonora Scenario:
### 120,000 AFY (107 MGD)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalination Facility</td>
<td>120,000 AFY (107 MGD)</td>
</tr>
<tr>
<td>78&quot; Pipeline</td>
<td>168 miles</td>
</tr>
<tr>
<td>Pump Stations</td>
<td>4 @ 6,000 hp; 1.1 MG forebays</td>
</tr>
<tr>
<td>System Storage</td>
<td>4 @ 25 MG</td>
</tr>
<tr>
<td>Power Demand</td>
<td>50 MW</td>
</tr>
</tbody>
</table>
# Regional Scenario: 1.2 MAFY (1.07 BGD)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalination Facility</td>
<td>1.2 MAFY (1 BGD)</td>
</tr>
<tr>
<td>Trapezoidal Canal (1.5H:1V)</td>
<td>143 miles</td>
</tr>
<tr>
<td>Pressure Pipe</td>
<td>25 miles</td>
</tr>
<tr>
<td>Pump Stations</td>
<td>5 @ 10,800hp; 11.1 MG forebays</td>
</tr>
<tr>
<td>System Storage</td>
<td>4 @ 25 MG</td>
</tr>
<tr>
<td>Power Demand</td>
<td>500 MW</td>
</tr>
</tbody>
</table>
Opinion of Delivered Cost
Arizona – Sonora Scenario: 120,000 AFY

<table>
<thead>
<tr>
<th>Arizona-Sonora Scenario</th>
<th>$/AF</th>
<th>$/1,000 gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline</td>
<td>1,732</td>
<td>5.32</td>
</tr>
<tr>
<td>SWRO Plant</td>
<td>995</td>
<td>3.06</td>
</tr>
<tr>
<td>Total</td>
<td>2,727</td>
<td>8.38</td>
</tr>
</tbody>
</table>

Includes:
- 250 MGD raw water intake structures
- 107 MGD MF/UF/RO plant
- 143 MGD concentrate ocean outfall
- 168-mile; 78-inch-diameter welded steel pipeline
- Four 6,000 hp pumping plants
- 100 MG of system storage
Opinion of Delivered Cost
Regional Scenario: 1.2 MAFY

<table>
<thead>
<tr>
<th>Regional Scenario</th>
<th>$/AF</th>
<th>$/1,000 gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal</td>
<td>278</td>
<td>0.85</td>
</tr>
<tr>
<td>SWRO Plant</td>
<td>905</td>
<td>2.78</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,183</strong></td>
<td><strong>$3.63</strong></td>
</tr>
</tbody>
</table>

Includes:
- 2,503 MGD raw water intake structures
- 1,070 MGD MF/UF/RO plant
- 1,433 MGD concentrate ocean outfall
- 143 miles of trapezoidal open canal
- 25 miles of dual, 180-inch welded steel pipeline sections
- Five 15,000 hp pumping plants
- 100 MG of system storage
## Cost Summary of Brackish Groundwater and Sea Water Desalination

<table>
<thead>
<tr>
<th>Source</th>
<th>Annual Volume</th>
<th>Recovery</th>
<th>$/AF</th>
<th>$/1000 gal</th>
<th>Brine Mgmt</th>
<th>Other Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brackish Groundwater</td>
<td>30,000 AF</td>
<td>85%</td>
<td>$1,836</td>
<td>$5.63</td>
<td>CP+BC+EP</td>
<td>Wellfield, Land, pipeline to distribution</td>
</tr>
<tr>
<td>Sea Water</td>
<td>120,000 AF</td>
<td>43%</td>
<td>$2,727</td>
<td>$8.37</td>
<td>Ocean dispersion</td>
<td>Wheeling, potable treatment, distribution</td>
</tr>
<tr>
<td>Sea Water</td>
<td>1,200,000 AF</td>
<td>43%</td>
<td>$1,183</td>
<td>$3.63</td>
<td>Ocean dispersion</td>
<td>Wheeling, potable treatment, distribution</td>
</tr>
</tbody>
</table>
Follow up to Sea of Cortez Study

• Additional investigations by Mexican University researchers have indicated that circulation patterns in upper Sea of Cortez show brine dispersion would be problematic

• Significant issues with getting anything done with Mexico
  • Priorities: shortage sharing, water supplies
  • Policy: SB1070
  • Leadership: Change is constant
  • Projects (Mexico) vs. Framework (U.S.)
Reclaimed Water Project

SALINITY RESEARCH ON CONCENTRATE MANAGEMENT PILOT DEMONSTRATION PROJECT
Salinity Research on Concentrate Management Pilot Demonstration Project (on reclaimed water)

1. Client: City of Phoenix on behalf of Sub-Regional Operating Group (SROG) Cities
   a. Glendale, Mesa, Phoenix, Scottsdale, Tempe

2. Scope: Conduct pilot scale testing on promising technologies to establish full-scale implementation guidelines for demonstrated technologies
   a. Recover water
   b. Reduce brine volume
   c. Use less energy & chemicals than brine concentrator

3. Currently underway
Reclaimed Water Quality Goals Vary Based on End Use

Irrigation - Crops
- TDS
- SAR or Sodium
- Boron
- Nutrient Recycle

Irrigation - Turf
- TDS
- SAR or Sodium
- Nutrient Recycle

Cooling Water
- Hardness or Calcium and Magnesium
- TDS vs. number of cycles
- Chloride and Sulfate versus infrastructure corrosion

Discharge
- Whole Effluent Toxicity (TDS, Chloride, etc.)

Recharge / Indirect Potable Reuse
- TDS, Inorganics, APP Permit
- TOC, TrOC
- AOP and RO Treatment vs. Fouling and Scaling Control

Tertiary RO
- Fouling Control: Colloidal, Organics, Biological
- Scaling Control: BaSO₄, Silica, Ca₃(PO₄)₂, etc.
Recommended Reclaimed Water Quality Goals Serve as a Planning Target for This Study, but Not for Policy Making

<table>
<thead>
<tr>
<th>Usage</th>
<th>TDS Goal (mg/L)</th>
<th>Other Special Goals (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turf / Crops Irrigation</td>
<td>&lt;1000</td>
<td>Na &lt; 150</td>
</tr>
<tr>
<td>Effluent Discharge Permit</td>
<td>&lt;1000</td>
<td>Chloride &lt; 150 – 250</td>
</tr>
<tr>
<td>Reuse Water as Cooling Water</td>
<td>&lt;1000</td>
<td>Note (1)</td>
</tr>
<tr>
<td>Indirect Potable Reuse / Recharge</td>
<td>&lt;500 – 700</td>
<td>APP Permit Action Levels, TOC Treatment</td>
</tr>
</tbody>
</table>

Note (1): Cooling water for PVNPGS shall be of the same quality as required by the discharge permit.
Previous CASS Work Developed Several Concentrate Management Alternatives, Including a “Baseline” ZLD Train

Desalination

Primary RO

Concentrate Pretreatment / Initial Volume Reduction

Softening

Filters

Secondary RO

Concentrate Volume Reduction

Brine Concentrator

Final Disposal / Use

Brine Line / Small Evaporation Pond

85% 95% ~99.5% Recovery (%)

1K 6-7K 17-20K ~100-200K TDS (mg/L)

1 mgd 53 acres 18 acres ~2 acres Pond Size
Minimizing Chemical and Energy Costs is the Key to Selecting the “Optimal” Concentrate Volume Reduction Alternative

<table>
<thead>
<tr>
<th>Primary RO</th>
<th>Secondary RO</th>
<th>Final Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalination</td>
<td>Concentrate</td>
<td>Brine Line / Small Evaporation Pond</td>
</tr>
<tr>
<td>Pretreatment / Initial Volume Reduction</td>
<td>Concentrate Volume Reduction</td>
<td></td>
</tr>
<tr>
<td>85%</td>
<td>95%</td>
<td>~99.5% Recovery (%)</td>
</tr>
<tr>
<td>1K</td>
<td>6-7K</td>
<td>17-20K</td>
</tr>
<tr>
<td>1 mgd</td>
<td>53 acres</td>
<td>~2 acres</td>
</tr>
<tr>
<td>18 acres</td>
<td>~100-200K TDS (mg/L)</td>
<td></td>
</tr>
</tbody>
</table>
There are Numerous “Cutting Edge” Technologies that can be Considered for Testing...

- VSEP
- SPARRO
- ED/EDR
- Secondary RO
- Capacitive Deionization (CDI)
- Aquaporins & Nano Engineered Membranes
- Direct Contact Membrane Distillation
- Brine Bulb Technology
- Multiple Effect Vacuum Distillation
- M3 Technology
- Reversible RO
- dRHS Technology
- Forward Osmosis
- SALPROC
Carollo’s prescreening yields the following short list...

**YES FOR PILOT**
- RO
- ED/EDR
- CDI
- VSEP
- FO
- MD, DCMD, VEMD, MEMD, BBT
- SPARRO
- C3
...

**MAYBE**
- EDM, EDI/CEDI, BMED
- Wetland
- Innovative Membrane Materials
- Electro-coagulation
- SSR / SALPROC
- M3 / RRO
...

**NO**
- Brine Concentrator
- Crystallizer
- Large Evaporation Pond
- DewVap
- Deep Well Injection
...

Softening, Chemical Precipitation With Filtration

Ion Exchange

AOP + Biological Treatment

GAC
Alternative Train 1: Organic Pretreatment (Biological Filters) + Inorganic Pretreatment + Electrodialysis (ED)

Desalination

Primary RO

Concentrate Pretreatment / Initial Volume Reduction

Advanced Oxidation Process (AOP)

Biological Filters

Polishing Filters

Electrodialysis

With or without ion switcher

Final Disposal / Use

Brine Line / Small Evaporation Pond

Pretreatment could also include softening

85% Recovery (%)

1K 6-7K TDS (mg/L)

1 mgd 53 acres

40~50K TDS (mg/L)

8~10 acres Pond Size
Alternative 2: FO / RO – Small Evaporation Pond

- **Desalination**
  - Primary RO

- **Concentrate Pretreatment / Initial Volume Reduction**
  - RO
  - Draw Solution Tank
  - FO 70-85% Recovery

- **Concentrate Volume Reduction**

- **Final Disposal / Use**
  - Brine Line / Small Evaporation Pond

- **Table**
  - Recovery (%): 97~98%
  - TDS (mg/L): 40~50K
  - Pond Size: 8~10 acres
  - 1 mgd 53 acres
Project Components

1. Collect preliminary data and cost information

2. Pretreatment Bench Scale Testing (for ED Train)
   a. Fouling Prevention from Organics & Scaling Prevention from Inorganics
      • Magnetic Ion Exchange (MIEX)
      • Advanced Oxidation Process
         - Ozone
         - O3/H2O2
         - UV/TiO2
      • GAC rapid small scale column test
      • Jar testing (coagulation, softening)
      • Ion Exchange (for sulfate)
Project Components (cont.)

3. Bench test ED (with and without pretreatment) and FO trains
4. Use bench scale testing data to develop pilot test protocols
5. Conduct pilot tests on ED and FO trains
6. Use pilot data to “scale up” costs for full scale implementation (91st Avenue WWTP and Scottsdale Water Campus)
7. Maintain CASMAT model for future evaluations of all SROG reclamation facilities
Proper Data Analysis Delivers SROG a "Toolbox" that Allows Full-Scale Implementation to Become a Reality

- Water Quality Data & Treatment Goals
- Client Expectations
- Expert Inputs
- Industry Status Review
- Capital, O&M and Life Cycle Costs
- Chemical Usage
- Energy Consumption
- Implementation Packages
SROG Concentrate Mgmt Study

Objective

1. Find lower cost (energy & chemical) alternative to softening, secondary RO, and brine concentrator
2. Recover as much water as possible
3. Manage a small volume of remaining waste
Summary

• New supplies, including locally available supplies, are going to cost an order of magnitude more than what is currently developed.

• Reuse, and customer ion-exchange softening of our source waters, increases TDS, and may increasingly require advanced treatment to maximize the secured resources.

• Scarcity, quality, and demand will drive how much we are willing to pay, and when.
  • There is a point of diminishing return on water recovery.