HYDROGEOLOGIC INVESTIGATION
OF THE
SCOTT M. MATHESON WETLAND PRESERVE
IN MOAB, UTAH

Funded by
The Nature Conservancy
State of Utah Department of Environmental Quality
Overview

• About the wetland
  – Hydrogeologic setting
  – Importance of wetland groundwater flow system

• Methods

• Results
  – Salinity and hydraulic head from different seasons
  – Geochemical signatures
    • Map out 2 separate flow systems
    • Delineate 3 GW sources
    • Show that the Colorado River is not a groundwater divide

• Conceptual Model of GW flow system

• Wetland water budget
The Scott M. Matheson Wetland Preserve

• Nature conservancy began acquiring land in 1990
• Unique & diverse desert environment along the Colorado River near Moab, UT
• Water is defining element
  - provides habitat for plants & animals not commonly found on the Colorado Plateau
Hydrologic Significance

• This wetland is the natural discharge area of the Spanish Valley alluvial aquifer
  – Tied to greater GW resources of valley

• Located in close proximity to 5th largest uranium tailings pile in U.S.

• Goals of Study
  – What is major source of water?
  – How much water is there?
  – Is the CR a groundwater divide?
• Mill Tailings
• Alluvial Fill & GCG Aquifer
• Springs along NE valley wall
• Average annual precipitation
  – 23 cm/yr in valley
  – 76 cm/yr in La Sal Mountains
• Mill Creek & Pack Creek
  – Drain west slopes of La Sals
  – Water diverted for irrigation
  – Kens Lake
• Cross section A-A’
• Spanish Valley – salt collapse valley

• 2 important groundwater sources
  – Valley-fill alluvial aquifer
  – Glen Canyon Group (GCG) bedrock aquifer
Previous Studies

- **Cooper & Severn, 1994** – *Wetland Ecology and Hydrology*
  - Springs from NE side of valley
  - Irrigation water from Mill Cr.
  - Said nothing of flow rates

- **Sumsion, 1971**
  - 11,000 acre-ft/yr passes through wetland

- **Rush et al., 1982**
  - 2,200 – 10,000 acre-ft/yr discharges into Colorado River

- **Downs & Kovacs, 2000.** – *Groundwater Model of Spanish Valley*
  - (13,000 acre-ft/yr) of regional GW passes through wetland
  - Mostly GCG water

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**Geochemistry of GCG water**

1. Low H (< 2 TU)
2. Stable isotopes that indicate high elevation precipitation ($\delta^{18}O = -15$ to $-14$ permil)
3. $R/R_a$ < 1
Sampling Sites

- 44 Monitoring Points
  - Both sides of river
  - Well nests
- Monitored over 2 years
  - Water levels
  - Salinity
- Measured
  - Uranium
  - Tritium
  - O and D isotopes
  - Dissolved gases
- Cross Sections
Subsurface Lithology

- Overbank deposits at surface - 5 - 6m of silt & sand
- Large continuous unit of gravel & cobbles in a sandy matrix
  - Clasts of pink granite, gneiss, & schist indicate CR deposition
- **Silts not very permeable**
  \( (K = 1.4 \times 10^{-5} \text{ m/s}) \)
- **Gravels are permeable**
  \( (K = 3.0 \times 10^{-3} \text{ m/s}) \)
Extent of CR Gravel Deposits

- High K layer is extensive
  - Continuous beneath river
  - Over 120 m thick near tailings
  - More than 40 m thick below wetland
Groundwater Salinity

- TDS in sampled waters range from 600 to 120,000 mg/L.
- Most *shallow* water on Preserve is 1,000 to 3,000 mg/L.
- 2 groundwater systems: Shallow fresh groundwater overlying brine.
Freshwater Potentiometric Contours, Summer 2003

- Horizontal flow perpendicular to contours
- Represents water table for shallow system composed of all fresh water.
- GW movement in shallow system generally toward river.
- Highest hyd. heads near springs along NE canyon wall
• GW movement in shallow system still generally toward river.

• Highest hyd. heads shifted to area of irrigated fields
Brine
Potentiometric Contours, Summer 2003

- Representative Slice
  - EFH values at 1190m elevation.
  - Within gravels

- Gradients are small but... Brine movement is from NW to SE beneath river
Brine Potentiometric Contours, Spring 2004

- Gradients still small
- Brine movement is now E to W
  - Possibly seasonal shift
  - Possibly DOE remediation
Uranium Distribution
Summer 2003

- Elevated levels in GW beneath preserve near Colorado River
  - 5.5 to 111 mg/L
  - anomaly at N3

- Decrease toward the SE

- Highest levels found in brine below top of channel gravels

- Head Gradient in brine suggest U migration from mill tailings & beneath the river
Tritium ($^3\text{H}$)

- $^3\text{H}$ – radioactive isotope of Hydrogen ($t_{1/2} = 12.3$ yrs)
- Prior to 1950, Utah precipitation had < 5 TU
- Atmospheric spike 1952 – 1969, increase of > $10^3$
- Ideal Environmental tracer for young waters (< 50 yr old)

- 1 TU = 1 $^3\text{H}$ per $10^{18}$ $^1\text{H}$
- Aquifer Recharge that occurred
  - < 1950 has < 1 TU
  - > 1950 has > 3 TU
Tritium ($^3$H)

- $^3$H ranged from < 0.1 to 17.6 TU
- Most fresh groundwater at the wetland has > 2 TU
  - Relatively young water
  - Exception is water from NE valley wall where GCG springs discharge
- x-section (mostly deeper wells)
  - Wetland shallow groundwater has moderate $^3$H
  - All brine has very low $^3$H
  - Highest $^3$H found in DOE wells and decreases with depth
  - Contaminated water (< 50 yrs. old) has penetrated brines

- Tritium ($^3$H)

  - Tritium measured in groundwater (TU)
  - Approximate interface between brine and fresh groundwater

  - A - A'
    - ATP-1 SMI-PZ1
    - N11 BL2
    - M11
    - BL3
    - N7
Oxygen and Hydrogen Isotopes

• Tracers that indicate
  – Meteoric water
  – Source water elevation
  – Evaporative history

• Reported in delta units (permil)

\[ \delta R = \left[ \frac{(R_{sample} - R_{std})}{R_{std}} \right] \times 1000 \]

where
\[ \delta R = \delta^{2}H \text{ or } \delta^{18}O \text{ in the water sample,} \]
\[ R_{sample} = {^{18}O/^{16}O} \text{ or } D/H \text{ ratio in the water sample, and} \]
\[ R_{std} = {^{18}O/^{16}O} \text{ or } D/H \text{ ratio in the reference standard (SMOW).} \]
Most water carries meteoric signal (including brine)

\[ \delta^{18}\text{O} = -15 \text{ to } -14 \] for high elev. precip.

\[ \delta^{18}\text{O} = -13 \text{ to } -12 \] for low elev. precip.
Distribution of Oxygen Isotopes

Evaporated Water

High elevation precipitation sourced from SE side of CR

Low elevation precipitation sourced from NW side of CR
Distribution of Oxygen Isotopes

High elevation precipitation sourced from SE side of CR

Low elevation precipitation sourced from NW side of CR

$\delta^{18}$-O measured in groundwater (permil)

Colorado River-15.2

Well screen / sampling point
Dissolve Gas Measurements – He isotopes

• Dissolved $^4\text{He}$
  – ranges over 2 orders of magnitude
  – delineates between upper and lower GW system better than salinity

• $\text{H}_2\text{O}$ in equilibrium with atmosphere…around $4.5 \times 10^{-8}$ ccSTP/g

• $^4\text{He}$ in excess of solubility is derived from decay of natural $^{238}\text{U}$, $^{235}\text{U}$, $^{232}\text{Th}$

• Avg. $^4\text{He}$ production rates in aquifer sediments
  – 0.28 to 2.4 $\mu$ccSTP m$^{-3}$ yr$^{-1}$
  – $10^5$ to $10^6$ yrs are needed to produce concentrations in brine

• $\frac{R}{R_a} = \frac{\left(\frac{^3\text{He}}{^4\text{He}}\right)_{\text{sample}}}{\left(\frac{^3\text{He}}{^4\text{He}}\right)_{\text{air}}}$
Dissolved Helium 4

- Shallow fresh water $^4$He around $5 \times 10^{-8}$ ccSTP/g
- Deep brine $^4$He as high as $7.4 \times 10^{-6}$ ccSTP/g
- $^4$He delineates a lower boundary to the shallow, more active GW system portion of the aquifer
- Boundary Depressed beneath mill tailings
Dissolved Helium 4

- In some locations, high $^4$He Boundary very shallow
- At CR1, brine only 2 m below the river
Sources of Wetland Water

Waters Grouped Spatially
- Blue are wells near springs
- Yellow are near irrigated fields
- Red are deep wells in brine
Green are mix of G1 & G2
Orange are mix of G2 & G3
Conceptual Model

- **Group 1**: Freshwater, GCG aquifer
- **Group 2**: Freshwater, valley-fill aquifer & irrigation return
- **Group 3**: Brine
- **Surface Water**

General direction of groundwater movement.

Areas of recharge or evaporation.

**Zone of mixing**
- Group 1 & Group 2 waters
- Group 2 & Group 3 waters

**Instruments**
- Brine Movement, Spring 2004
- Brine Movement, Summer 2003

**Features**
- Highway 191
- Springs
- Irrigated Fields
- Colorado River
- Potentiometric contours (0.5 m intervals)
• **Geochemistry** – improved knowledge of water sources
  - Mostly irrigation and local valley GW, not much GCG water
• **Seasonal monitoring** - improved estimates of discharge to river
  - Less than 10m relatively fresh water above brine
  - Know hydraulic gradients
  - Know lithology and approximate conductivity
# Wetland Water Budget

<table>
<thead>
<tr>
<th>INFLOW COMPONENTS</th>
<th>(acre-ft/yr)</th>
<th>Source</th>
<th>Degree of Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>450</td>
<td>Steiger and Susong, 1997</td>
<td>Low</td>
</tr>
<tr>
<td>Major Springs:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Skakel</td>
<td>390</td>
<td>Christie, 2003; Sumson, 1971</td>
<td>Moderate*</td>
</tr>
<tr>
<td>Watercress</td>
<td>50</td>
<td>Christie, 2003;</td>
<td></td>
</tr>
<tr>
<td>Mill Creek Irrigation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Returns</td>
<td>1,650</td>
<td>MIC and UDWR, 2003, this study</td>
<td>Moderate*</td>
</tr>
<tr>
<td>Groundwater in</td>
<td>766 – 2,170</td>
<td>Balance = outflows - inflows</td>
<td>Moderate - High</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>OUTFLOW COMPONENTS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Evapotranspiration</td>
<td>3,200</td>
<td>Crowley, 2004; Sumson, 1971</td>
<td>Low – Moderate*</td>
</tr>
<tr>
<td>Groundwater out</td>
<td>106 – 1,512</td>
<td>this study</td>
<td>Moderate – High*</td>
</tr>
</tbody>
</table>

* Doubling outflow and reducing contributions of springs and irrigation waters by ½ - groundwater inflow = 4,730 acre-ft/yr
Previous Studies Revisited

- Sumsion, 1971
  - 11,000 acre-ft/yr passes through wetland

- Rush *et al.*, 1982
  - 2,200 – 10,000 acre-ft/yr discharges into Colorado River

- Downs & Kovacs, 2000. – *Groundwater Model of Spanish Valley*
  - (13,000 acre-ft/yr) of regional GW passes through wetland – most GCG water

Image: Aerial view of Spanish Valley and Wetland with flow indicators showing 766 – 2,170 acre-ft/yr movement.
Conclusions – *Freshwater Sources*

- Shallow lens of fresh groundwater on top of brine
- Seasonal shifts in flow direction
  - (more from Skakel & Watercress springs when less irrigation and water is available)
- Only 6% – 36% of the predicted 13,000 acre-ft/yr actually reaches wetland
- Geochemically, most wetland groundwater is very different than GCG water
  - Nearby irrigation return from Mill Creek diversions
  - Valley-fill aquifer water from up valley irr. or Ken’s lake leakage
Conclusions –
River as Groundwater Divide

- River is NOT a hydrologic boundary
  - EFH & lithology show potential exists
  - Oxygen isotopes show that water recharged on north side exists beneath the wetlands
Uncertainties Remain

• While there is no immediate threat, present rate of contaminant movement and discharge locations from mill tailings are unknown
  – Some brine likely discharges into river where silt is scoured to gravels

• Connection between salty contaminated water beneath the tailings/wetlands and alluvial aquifer of Spanish Valley

• Driving forces that influence brine
  – Summer consumption of fresh GW in Moab
  – DOE remediation project (pump & treat system)

• Water budget could be refined
  – Gauging all surface water inflows
3 Groups

$^3$H (TU)

$^{18}$O

$R/R_o$

TDS (mg/L)
Orange are mix of G2 & G3

$\delta^{18}O$

N8 and M11 are Evap. enriched
Methods...

What was done and why

• Examined subsurface lithology.
  – Core from 3 boreholes drilled on wetland.
  – Logs from 15 DOE wells around Mill Tailings.
• Monitored water levels and salinity seasonally for 2 yrs.
• U concentrations sampled during summer 2003.
• Tritium (³H) measured from fall 2002 to summer 2003.
• O and D isotopes measured in spring and summer 2003.
• Dissolved noble gases measured in spring and summer 2003 with emphasis on He isotopes.
Wetland Water Sources – Is it GCG water?

3 springs and 2 wells that yield GCG water have been sampled.

1. Low $^3$H ($< 2$ TU)

2. Stable isotopes that indicate high elev. precipitation ($\delta^{18}O = -15$ to $-14$ permil)

3. $R/R_a < 1$
Water Budget, refined est. of inflows & outflows

- Mill Creek Irrigation Diversions, significant inflow
  - MIC map of diversions & irrigated fields
  - Flow records from UDWR
  - Diversion – Crop ET = surface & shallow GW to the wetland
  - \((dh/dl) = 0.005\)

- Freshwater above brine, < 10m saturated thickness
  - \(Q = A*K*(dh/dl)\)
  - \(K = 1.9 \times 10^{-5} \text{ to } 2.7 \times 10^{-4}\)
  - \(A = 10 \text{ m } * 4.4 \text{ km}\)
  - \((dh/dl) = 0.005\)

- Wetland ET = 3,000 acre-ft/yr
  - Crowley, 2004; Sumsion, 1971