The Effect of GSL Salinity on Magnesium Production (and on the other South Arm Mineral Extraction Industries)
US Magnesium LLC

- A privately held company owned by The Renco Group, a family of industrial companies that besides magnesium include assets in automobile components, steel, lead, energy and specialized vehicle production (AM General).

- Only producer of primary magnesium in the United States (and North America.) It is currently the largest single site for magnesium production.

- US Magnesium employs about 550 workers

- US Magnesium has operated since 1972
Mineral Extraction on the Great Salt Lake

There are three major mineral extraction operations on the South Arm of Great Salt Lake:

- Morton Salt
- Cargill Salt
- US Magnesium
US Magnesium’s Solar Ponds

- Provide concentrated magnesium chloride solutions for the production of magnesium metal.

- The solar ponds comprise 75,000 acres (+115 sq. miles) – about 6% of the Lake bed.
US Magnesium’s Solar Ponds

US Magnesium operates:

- With a mineral extraction permit issued by the State [ML18779]
- With various water rights on the Lake
Process Flow Diagram
Brine is processed via a multi-step process to manufacture magnesium and chlorine.
Attractive Properties of Magnesium

- Light Weight (low density)
- High Strength (high strength to weight ratio)
- Unique Chemical/Mechanical Properties
  - Unique metal crystal structure
  - High electrochemical potential
- Others
There are many uses of Magnesium.

Magnesium

- Beer cans
- Fireworks
- Alloying with titanium
- Medicine
- Electronic components
- Automotive parts

TiCl₄

Ti
US Magnesium’s Other Products (derived from the Lake)

- Chlorine
- Hydrochloric acid (up to food grade)
- Ferrous chloride
- Calcium chloride
- Magnesium chloride solutions
- Sodium chloride
- Exploring the production of lithium carbonate
Great Salt Lake Water – where it all starts

- **Composition of the water in the South Arm GSL:**
  - Chloride (Cl⁻) 8.2%
  - Sodium (Na⁺) 5.1%
  - Sulfate (SO₄²⁻) 1.1%
  - **Magnesium (Mg²⁺) 0.45%**
  - Potassium (K⁺) 0.3%
  - Lithium (Li⁺) 0.002% (20 ppm)
  - Also BO₃⁺, Rb⁺, Ca²⁺, HCO₃⁺, other odds and ends

- Salinity is the sum of the dissolved ionic species in the water
US Magnesium’s Solar Ponds

- Annual water input to the solar ponds is 30 to 40 billion gallons

- The current magnesium concentration is about 0.4% Mg or 1.6% MgCl₂
During the hottest part of the evaporative season, evaporation reaches around a million gallons per minute.

Product brine concentration must be a minimum of 8.5% Mg (36% MgCl$_2$)
The solar ponds operate in a continuous flow like a slow moving river.

- Mg Concentration Increases
- Brine Depth Decreases

0.45% Mg

>8.5% Mg

3’-4’

4’’-6’’
## Composition of the finished solar pond brine

<table>
<thead>
<tr>
<th></th>
<th>Finished Brine</th>
<th>(Initial South Arm GSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride (Cl(^-))</td>
<td>24.7%</td>
<td>(8.2%)</td>
</tr>
<tr>
<td>Sodium (Na(^+))</td>
<td>0.11%</td>
<td>(5.1%)</td>
</tr>
<tr>
<td>Sulfate (SO(_4^{+2}))</td>
<td>2.5%</td>
<td>(1.1%)</td>
</tr>
<tr>
<td><strong>Magnesium</strong> (Mg(^{+2}))</td>
<td><strong>8.9%</strong></td>
<td>(0.5%)</td>
</tr>
<tr>
<td>Potassium (K(^+))</td>
<td>0.6%</td>
<td>(0.3%)</td>
</tr>
<tr>
<td>Lithium (Li(^+))</td>
<td>0.075%</td>
<td>(0.002%)</td>
</tr>
</tbody>
</table>

Magnesium is concentrated by about 20X processing through the solar ponds.
The capacity of a solar pond operation is a function of area, net evaporation rate (weather) and input concentrations (salinity.)

Everything else being equal, higher input (salinity) concentrations equal higher solar evaporation output capacity.

Lower input concentrations (salinity) equates to lower production capacities.
GSL Salinity

- The salinity is determined by the total dissolved salt content and the volume of the Lake.

- In general you’d expect that:
  - Higher Lake surface elevation bring lower salinity and
  - Lower Lake elevations bring higher salinity.

- Before the Lake was segmented by the SPRR causeway those rules applied – since then not so strictly.
<table>
<thead>
<tr>
<th>Year</th>
<th>Lake Elev.</th>
<th>%Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>4197</td>
<td>1.1%</td>
</tr>
<tr>
<td>1980</td>
<td>4197</td>
<td>0.86%</td>
</tr>
<tr>
<td>2002</td>
<td>4197</td>
<td>0.49%</td>
</tr>
<tr>
<td>2010</td>
<td>4197</td>
<td>0.54%</td>
</tr>
<tr>
<td>2018</td>
<td>4195</td>
<td>0.43%</td>
</tr>
</tbody>
</table>
What has caused the shifts in South Arm salinity?

- The SPRR causeway 1959
- West end causeway breach of 1985
- Compaction of the causeway fill

West End Breach in the Causeway - 1985
What has caused the shifts in South Arm salinity?

- 600 million tons of salt sent to the West Desert in 1987 to 1990
- North arms saturation since 1992 (storing salt in the floor)
- Collapse of the causeway culverts 2013
- The new RR bridge of 2017?
Effect of Lower Salinity on Magnesium Production?

- Lower input salinity equates to lower overall production of raw material brine for magnesium production.

- Due to certain system improvements, the US Magnesium Solar Ponds still have some extra capacity during “normal” weather patterns.
Some Solutions for lower Salinity in the South arm

- Add more solar pond area to the current pond operations
- Take input brine for the Stansbury Basin ponds from the North Arm of the Lake (via canal)
- Add additional openings in the causeway to have more homogenous and constant Lake salinity
Questions??

- Magnesium, a Metal for the Future:
  - Is versatile
  - Has unique properties
  - Is widely accepted by industry and consumers

- US Magnesium expects to fill the need for a long time