**PROBLEM STATEMENT**
Design a cryo-purification process that treats 30,000 bbl/day of oil produced water to a maximum impurity level of 3,500 mg/L TDS for agricultural irrigation.

Utilize Alberta’s freezing ambient winter temperatures to drive energy savings.

**PROJECT DRIVERS**
- 50% of global population experiences severe water scarcity at least once a year.
- 51 water shortage advisories currently in place for select water management areas across Alberta.
- 60% of consumed water in Alberta is for agricultural irrigation.
  - Alberta produces 486.4 thousand bbl/day of crude oil.
  - For each barrel of oil 3-10 barrels of water is produced.
  - But oil produced water is too unsafe for re-use and is disposed by deep well injection.
  - Deep well injection costs $1.60 - $2.10 per barrel.
- Current non-scalable produced water treatment processes range from $2.55 - $10.

**PROCESS SAFETY CONSIDERATIONS**
- Cold PPE requirement for operators due to low temperature operating conditions.
- Moving mechanical parts require special operator training and emergency shut-down procedures.
- Chloride ions cause equipment corrosion so 316 stainless steel was used for exposed equipment.
- CO2 refrigerant may cause asphyxiation, requiring use of a ventilation system and safety control valves to prevent leaks.

**ENVIRONMENTAL CONSIDERATIONS**
- Reinjection has been related to seismic events; however, we are reducing the overall reinjection requirements by 66%.
- Spills will be a more concentrated brine than typical produced water. The process will be located near the reinjection well to reduce risk.
- 7.9 kgCO2e/bbl GHG emissions. A renewable electricity source is needed to minimize the emission intensity of the process.

**PRODUCT REGULATIONS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Feed</th>
<th>Product</th>
<th>Ab Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Adsorption Ratio (SAR)</td>
<td>N/A</td>
<td>145</td>
<td>11</td>
<td>6 - 12</td>
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<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>mg/L</td>
<td>102,160</td>
<td>3,475</td>
<td>&gt;3,500</td>
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<tr>
<td>Electrical Conductivity</td>
<td>dS/m</td>
<td>8.064.9</td>
<td>1.5±0.4</td>
<td>0.5 - 1.9</td>
</tr>
</tbody>
</table>

**PROCESS OVERVIEW**

De-oiled Produced Water

30,000 bbl/d

~ 100,000 mg/L TDS

Pre-treatment

Cooling

Cooling + Freezing

Ice & brine slurry

Recycle

Separation by Flotation

Unwashed ice

Recycle

Washing

Purified ice

Recovery

Melting

19,666 bbl/d

~ 3500 mg/L

Irrigation water

10,334 bbl/d

~ 296,000 mg/L

Brine for reinjection

**ECONOMICS**

- **Total Capital Investment (TCI)**: $247,000,000
- **Operating expenses (OPEX)**: $26,400,000
- **Revenue/bbl_product**: $2.03
- **Revenue/bbl_product** Project Break-Even Revenue/bbl_Product: $1.64

**ACKNOWLEDGEMENTS**
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