GROUNDWATER COMPONENT IN MINING OPERATION-MINING HYDROLOGY

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MINING HYDROLOGY

Hydrology

Surface-Water Hydrology

Groundwater Hydrology

Hydrogeology (Geohydrology?)

Groundwater Hydraulics

Aqueous Geochemistry

“Mining Hydrology”

Depressurization

Disposal

Drainage

Water Supply

Input to Geotechnical Analysis and Design

Environmental Impacts
1. Dewatering
   • Drainage
   • Depressurization
   • Disposal
2. Process
   • Water Supply
   • Tailings
   • Heap Leach
   • Excess/Spent/Fugitive
3. Environmental
   • Seepage (Adits/Portals/Underground)
   • Pit Lakes
   • Waste Rock
   • Process/Dewatering
DEWATERING
Dewatering Terminology

- **Dewatering** – Draining and/or depressurizing
- **Active dewatering** – wells, drains, galleries, trenches
- **Passive Inflow** – seepage
- **Residual passive inflow** – seepage during active pumping

**Diagram:**
- **GROUT OR FREEZE WALL**
- **ULTIMATE PIT BOUNDARY**
- **PERIMETER WELL**
- **IN-PIT WELL**
- **DRAINAGE GALLERY WITH DRAINHOLES**
- **SUMP**
- **SUB-HORIZONTAL DRAINHOLES**

*ITASCA*
**Specific yield** ($S_y$) - Volume of water released from storage per unit area per unit decline of the water table.

**Specific Storage** ($S_s$)
Volume of water released from storage from a unit volume of aquifer per unit decline in hydraulic head.
DRAINAGE VS. DEPRESSURIZATION
HOW MUCH WATER?

Volume (drainage)
\[ V = A \times S_y \times \Delta h \]
\[ = 1 \text{ m}^2 \times 0.01 \times 1 \text{ m} \]
\[ = 0.01 \text{ m}^3 \]

Volume (depressurization)
\[ V = V \times S_s \times \Delta h \]
\[ = 100 \text{ m}^3 \times 10^{-6} \text{ m}^{-1} \times 1 \text{ m} \]
\[ = 0.0001 \text{ m}^3 \]
# Dewatering Rates at Mines Throughout the World

<table>
<thead>
<tr>
<th>Mine/Project Company</th>
<th>Location</th>
<th>General Geology of Country Rock</th>
<th>Dewatering Rate (m³/day)</th>
<th>USgpm</th>
<th>Primary Method of Dewatering</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldstrike</td>
<td>Barrick</td>
<td>Nevada, USA, Metasediments</td>
<td>381,500</td>
<td>69,800</td>
<td>perimeter wells</td>
<td>includes underground mine</td>
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<tr>
<td>Konkola</td>
<td>Vedanta</td>
<td>Zambia, Carbonates</td>
<td>280,000</td>
<td>51,200</td>
<td>underground sumps</td>
<td></td>
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<tr>
<td>Lone Tree</td>
<td>Newmont</td>
<td>Nevada, USA, Metasediments</td>
<td>273,000</td>
<td>50,000</td>
<td>perimeter wells</td>
<td>now in closure</td>
</tr>
<tr>
<td>Pine Point</td>
<td>Cominco</td>
<td>NWT, Canada, Carbonates</td>
<td>227,000</td>
<td>41,500</td>
<td>perimeter wells</td>
<td>total from 9 pits; now closed</td>
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<tr>
<td>Grasberg</td>
<td>Freeport</td>
<td>Indonesia, Carbonate</td>
<td>190,000</td>
<td>34,800</td>
<td>passive underground drainholes</td>
<td></td>
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<tr>
<td>Leeville</td>
<td>Newmont</td>
<td>Nevada, USA, Metasediments</td>
<td>136,000</td>
<td>24,900</td>
<td>perimeter wells</td>
<td>underground mine</td>
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<tr>
<td>Cove (McCoy)</td>
<td>Echo Bay</td>
<td>Nevada, USA, Metasediments</td>
<td>120,000</td>
<td>22,000</td>
<td>perimeter wells</td>
<td>now in closure</td>
</tr>
<tr>
<td>Victor</td>
<td>De Beers Canada</td>
<td>Ontario, Canada, Carbonates</td>
<td>120,000</td>
<td>22,000</td>
<td>perimeter wells (planned)</td>
<td>predicted with model</td>
</tr>
<tr>
<td>Snap Lake</td>
<td>De Beers Canada</td>
<td>NWT, Canada, Granitic</td>
<td>100,000</td>
<td>18,300</td>
<td>underground sumps</td>
<td>predicted with model</td>
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<tr>
<td>Gold Quarry</td>
<td>Newmont</td>
<td>Nevada, USA, Metasediments</td>
<td>109,000</td>
<td>19,900</td>
<td>perimeter wells</td>
<td></td>
</tr>
<tr>
<td>Lisheen</td>
<td>Anglo American</td>
<td>Ireland, Carbonates</td>
<td>90,000</td>
<td>16,500</td>
<td></td>
<td></td>
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<tr>
<td>Fort a la Corne</td>
<td>Shore Gold</td>
<td>Saskatchewan, Canada, Sandstone</td>
<td>80,000</td>
<td>14,600</td>
<td>perimeter wells (possible)</td>
<td>Not developed yet; predicted with preliminary model</td>
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<tr>
<td>Twin Creeks</td>
<td>Newmont</td>
<td>Nevada, USA, Metasediments</td>
<td>38,000</td>
<td>7,000</td>
<td>perimeter wells</td>
<td></td>
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</tbody>
</table>
DEWATERING PROGRAMS CAN BE LARGE
LOTS OF SOURCES – VARIABLE FLOWS AND WATER QUALITY

Inflow

Time

Total Water to be Managed
Passive Inflow
Active Dewatering
Residual Passive Inflow
End of Mining

Sub-horizontal drain holes
In-pit sump
Underground Drainage Gallery
Residual Passive Inflow
DEWATERING WATER QUALITY

- Integral to water management
- Determines use/disposal
- May require treatment during operations
  - How much water
  - What constituents
  - What concentrations
- Can be used to identify source of inflow
WATER DISPOSAL

Options for water disposal:

1. Mining / milling usage
2. Discharge to surface drainage
3. Rapid infiltration basins (RIBs)
4. Injection into basin-fill and/or bedrock
5. Agricultural use
6. Enhanced evaporation (within consumptive use limits)
7. Temporary storage in surface impoundment (water later released into pit after mining ceases)
RIBS

Cons
• Water-quantity
• Water-quality
• Performance

Pros
• Return water to aquifer
• No inter-basin transfer
• Less sensitive than surface disposal
• More practical than injection
PROCESS WATER QUESTIONS

• Water Supply
  – Where will the water come from?
  – Will it need to be treated?

• Process
  – Where will the water end up?
  – What will its chemistry be?
  – Will my operation degrade water quality or quantity?
  – What about closure conditions (e.g., pit lake, heap/tailings draindown)?
  – Where is constituent X coming from and how do we clean it up?
  – How is the water best managed?
  – How do I treat the water?
  – How much will it cost?
WATER SUPPLY

Wells are expensive!
PACKER SYSTEM

- Hydraulic testing (productivity)
- Sampling (water quality)
SAMPLING REPRESENTATIVE?

• Comparison of Samples
  – Open Hole (airlift-unfiltered)
  – Well (micropurge-filtered)

• Similar
  – Water type
  – General chemistry

• Not so similar
  – Redox (e.g. sulfur)
  – Metals
ENVIRONMENTAL
CHARACTERIZE THE SYSTEM

• Type and amount of materials
• Acid-generation
• Metals leaching
• Variability (Spatial/temporal/scale)
• Climate
• Water management plan
MODELING
ESTIMATING DEWATERING CHEMISTRY

1. Use readily available data
   - Exploration water samples
   - Monitoring samples
   - Dewatering samples
   - Exploration assay data

2. Consider heterogeneity/compartmentalization

3. Use geostatistical tools to develop 3D model

4. Test model (theoretical or additional data)

5. Develop estimated ranges for areas of interest
PIT-LAKE WATER QUALITY

- Important for closure planning
- Predictions required by regulators
- Uncertainty in predictions
- Can be challenging to treat
  - Large volumes
  - Stratification
  - Access
CONCLUSIONS

• Groundwater is integral in mining operations (as an operational impediment, an operational resource, and an environmental resource)

• Some projects require moving/treating large amounts of water

• Treatment is important for both environmental and engineered process systems

• Environmental treatment may be needed long after closure

• Water-management planning is critical
QUESTIONS?