Ten-Year Performance Evaluation of the Evapotranspiration Cover at Barrick Goldstrike Mine’s AA Leach Pad

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Thanks to Dale Hammermeister and Joe Vinson
Background

- Goldstrike Mine located in north-central Nevada
  - Average precipitation = 11.7 in/yr (29.7 cm/yr): 1990-2011
  - Primarily snow, December through May
- AA Leach Pad
  - HDPE lined gold heap leaching facility
  - Operated from 1987 to 1999
  - 224 acres and 55 million tons of ROM leached ore
- Estimates of natural groundwater recharge rates
  - Function of elevation and precipitation
  - Maxey-Eakin (1949) approximation – 3% to 5% of precipitation
- Evapotranspiration (ET) cover designed and placed in 2000-2001
Barrick Gold Closure Objectives

Continuous Improvement

Concept Development

Design

Construction

Performance Monitoring

Evaluation & Refinement
Designing an ET Cover

ET Cover – Seasonal storage and release of soil water

1. Fall

Soil is initially dry due to previous growing season
Designing an ET Cover

2. Winter
Rain and snowmelt gradually infiltrates, increasing soil water

ET Cover – Seasonal storage and release of soil water
Designing an ET Cover

ET Cover – Seasonal storage and release of soil water

3. Spring

Net percolation is most likely in this season (April-June) after a wet winter
ET Cover –
Seasonal storage and release of soil water

4. Late Spring & Early Summer
Temperature warms, and evapotranspiration increases
ET Cover – Seasonal storage and release of soil water

5. Late Summer
Continued transpiration by vegetation removes stored soil water from root zone
Designing an ET Cover

**Design Factors**

- Cover should contain ample water-holding capacity (loams ideal)
- An abrupt textural contrast from loams/silts to gravel/sands may create capillary break

- Downward/upward flux rates are controlled by soil hydraulic properties and pressure potential gradients
- Zero flux plane defines depth at which downward flux is occurring
AA Pad Closure

- ET Cover Design Parameters
  - Minimize net percolation from meteoric water
  - Promote vegetation growth
- Borrow material: fine grained topsoil or valley fill deposits (Carlin silt)
  - Unsaturated flow modeling predicted nominal changes in flux above a 4 foot ET cover
- Four foot ET cover (3 ft to 5.5 ft), placed in 2000-2001
AA Pad Cover Performance Monitoring

- Soil cover monitoring stations (14)
  - Soil water dynamics (water content, soil water pressure potential)
  - In-situ and laboratory hydraulic property characterization
  - Various monitoring locations to access solar aspect, slope location, proximity to runoff channels, cover material type
    - East transect – Carlin Silt, east aspect
    - West transect – Topsoil, north aspect
    - South transects - Carlin Silt, south aspect
  - Station installation 2001 (East and West) and 2005 (South)

- Estimate net percolation:
  - Use 1D Darcy approximation using pressure potential data and hydraulic properties from bottom two sensor locations
Figure 2. Monitoring sites at AA Pad
DATA LOGGER

30 cm below ground surface
40 cm above contact
10 cm above contact
10 cm below contact

Carlin Silt (AA Pad East) or Top Soil (AA Pad West) Cover

Leach Ore (AA Pad East and West)

LEGEND:
- WATER CONTENT PROBE
- HEAT DISSIPATION SENSOR (HDS)

NOT TO SCALE
Sensor Installation
Data Summary
Vegetation Data
## Vegetation after 10 years

<table>
<thead>
<tr>
<th>Ground Cover Type</th>
<th>Transect</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>East</td>
<td>South</td>
<td>West</td>
</tr>
<tr>
<td>Total Plant</td>
<td>26%</td>
<td>36%</td>
<td>89%</td>
</tr>
<tr>
<td>Perennial</td>
<td>24%</td>
<td>31%</td>
<td>88%</td>
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<tr>
<td>Shrub and Forb</td>
<td>17%</td>
<td>21%</td>
<td>87%</td>
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</tbody>
</table>
Water Content Data
West Transect Water Storage

![Graph showing water storage and precipitation over time.](image-url)

- **Date**: Jan-01 to Jan-12
- **Water Storage (cm)**: Y-axis
- **Daily Precipitation (cm)**: Y-axis
- **Key**:
  - W1 - Crest
  - W2 - Mid-slope
  - W3 - Mid-slope
  - W4 - Foot-slope
  - W5 - Foot-slope
  - Precipitation
## Field Water Holding Capacity

<table>
<thead>
<tr>
<th>Location</th>
<th>Cover Thickness (cm)</th>
<th>Average Maximum Cover Water Content (cm)</th>
<th>Average Minimum Cover Water Content (cm)</th>
<th>Estimated Plant-Available Water (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carlin Silt Cover</strong></td>
<td></td>
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<tr>
<td>East Transect Average</td>
<td>104</td>
<td>17.2</td>
<td>8.7</td>
<td>8.5</td>
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<tr>
<td>East Transect Std Dev</td>
<td>13.0</td>
<td>3.5</td>
<td>2.5</td>
<td>1.3</td>
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<tr>
<td>South Transect Average</td>
<td>151</td>
<td>25.7</td>
<td>16.9</td>
<td>8.8</td>
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<tr>
<td>South Transect Std Dev</td>
<td>57.5</td>
<td>8.8</td>
<td>7.4</td>
<td>4.8</td>
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<tr>
<td>Carlin Average</td>
<td>120</td>
<td>20</td>
<td>11.4</td>
<td>8.6</td>
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<tr>
<td><strong>Topsoil Cover</strong></td>
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<td></td>
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<td></td>
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<tr>
<td>Topsoil Average</td>
<td>145</td>
<td>26</td>
<td>10.2</td>
<td>15.8</td>
</tr>
<tr>
<td>Topsoil Std Dev</td>
<td>14.0</td>
<td>3.4</td>
<td>1.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>
Pressure Potential Data
West 2 Matric Potential

Cover Thickness 134 cm

Increasing dryness

Date

- 30 cm
- 94 cm
- 124 cm
- 144 cm (leached ore)
- Precipitation

Daily Precipitation (cm)

Matric Potential (cm)
East 4 Matric Potential

Cover Thickness 90 cm

Increasing dryness

Daily Precipitation (cm)

Matric Potential (-cm)

Date

Jan-01, Jul-01, Jan-02, Jul-02, Jun-03, Jul-03, Jan-04, Jul-04, Jun-05, Jul-05, Jun-06, Jul-06, Jan-07, Jul-07, Jun-08, Jul-08, Jun-09, Jul-09, Jan-10, Jul-10, Jun-11, Jul-11, Jan-12

Legend:
- 30 cm
- 50 cm
- 80 cm
- 100 cm (leached ore)
- Precipitation
Estimated Net Percolation Fluxes
Estimated Cumulative Flux East Transect

Cumulative Annual Precipitation (cm)

Date

- Carlin Crest (E-1)
- Carlin Mid-slope (E-2)
- Carlin Mid-slope (E-3)
- Carlin Foot-slope (E-4)
- Precipitation
Estimated Cumulative Flux Channels
Estimated Cumulative Flux West Transect

Cumulative Annual Precipitation (cm)

Cumulative Flux (cm, +down / -up)

Topsoil Crest (W-1)
Topsoil Mid-slope (W-2)
Topsoil Mid-slope (W-3)
Topsoil Mid-slope (W-4)
Topsoil Foot-slope (W-5)
Precipitation
Estimated Cumulative Flux South Transect

Cumulative Flux (cm) (+down / -up)

Precipitation

Carlin Crest (S-1)  Carlin Mid-slope (S-2)  Carlin Foot-slope (S-3)  Precipitation

Date

Cumulative Annual Precipitation (cm)

Jul-02  Dec-02  Jan-03  Jul-03  Jan-04  Jul-04  Jan-05  Jul-05  Jan-06  Jul-06  Jan-07  Jul-07  Jan-08  Jul-08  Jan-09  Jul-09  Jan-10  Jul-10  Jan-11  Jul-11  Jan-12
Estimated Cumulative Flux South WFMs
Summary of Monitoring Data

- Average precipitation during monitoring period (2001-2011) was 13.6 in/yr (34.5 cm/yr)
  - 2004-2005 wettest year in 35 years (Elko, NV)
- Estimated net percolation (from pressure potential monitoring data) as percent of annual precipitation:
  - 0.7% for topsoil and 1.5% for Carlin
  - 3.7% for Carlin channels
  - Area weighted average ≈ 0.85%
- Significantly higher estimated net percolation in channels, some evidence of downslope water accumulation
- Average and dry years - little to no deep percolation
- Observed ET and rooting from greater than 5 feet
Drain-down – base flow = 0.43 cm/yr  
(1.3% precipitation)
Conclusions

- ET cover has sufficient water storage, variable
- Majority of net percolation is episodic, channels are foci
- Estimated net percolation is well below regional estimates of recharge
  - Topsoil shows best performance, Carlin adequate
  - Variable soil and vegetation characteristics, rooting is not limited to cover material
- Generally good agreement between monitoring data and draindown data
- Multiple years of monitoring necessary
Maxey-Eakin Estimated Recharge (White River Valley, NV, 1949)
Vegetation after 10 years

Ground Cover Type

Transect

East South West

Total Plant 26% 36% 89%
Perennial 24% 31% 88%
Shrub and Forb 17% 21% 87%

Kochia prostrata
Agropyron (Wheatgrasses)
Elymus cinereus (Great Basin Wildrye)
Poa (Bluegrasses)
Bromus tectorum (Cheatgrass)

Atriplex Canescens (4-wing saltbush)
Purshia Tridenta (Bitterbush)
## Estimated Net Percolation (Pressure Potential data)

<table>
<thead>
<tr>
<th>Station</th>
<th>Water Years 2003-2011</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average Annual Flux</td>
<td>Average Flux as % of Precip</td>
</tr>
<tr>
<td></td>
<td>(cm)</td>
<td>(%)</td>
</tr>
<tr>
<td><strong>Carlin Silt Cover</strong></td>
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<tr>
<td>Carlin East Transect Average</td>
<td>0.76</td>
<td>2.1</td>
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<td>Channel Carlin East Transect Average</td>
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<td>3.7</td>
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<tr>
<td>Non-Channel Carlin East Transect Average</td>
<td>0.47</td>
<td>1.3</td>
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<tr>
<td>Carlin South Transect Average</td>
<td>0.08</td>
<td>0.26</td>
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<tr>
<td>Carlin Silt Stations Average</td>
<td>0.59</td>
<td>1.49</td>
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<tr>
<td><strong>Topsoil Cover</strong></td>
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<tr>
<td>Topsoil Stations Average</td>
<td>0.24</td>
<td>0.67</td>
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<tr>
<td><strong>All Stations Average</strong></td>
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<tr>
<td>All Stations Average</td>
<td>0.42</td>
<td>1.2</td>
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<tr>
<td>Area Weighted Station Average</td>
<td>0.30</td>
<td>0.85</td>
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