**Abstract:**

AA Leach Pad at Barrick Goldstrike Mine was reclaimed using an evapotranspiration (ET) cover designed to limit the infiltration of precipitation into the facility. Cover performance monitoring sensor stations were installed in the cover and underlying leach material after cover system placement. Monitoring of the sensor nests continued for eleven years. Data indicates that the cover is performing well, limiting net percolation to less than 1% of annual precipitation. AA Leach Pad is the first large-scale closed mine waste facility which has been robustly monitored for a relatively long time in Nevada, USA. Results from the cover monitoring study provide an understanding of ET cover system performance for closure of other mine waste facilities, and offer guidance for ET cover system requirements in other arid regions.
Technical Article

11 Year Evapotranspiration Cover Performance Summary - AA Leach Pad at Barrick Goldstrike Mines

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Abstract AA Leach Pad at Barrick Goldstrike Mine was reclaimed using an evapotranspiration (ET) cover designed to limit the infiltration of precipitation into the facility. Cover performance monitoring sensor stations were installed in the cover and underlying leach material after cover system placement. Monitoring of the sensor nests continued for eleven years. Data indicates that the cover is performing well, limiting net percolation to less than 1% of annual precipitation. AA Leach Pad is the first large-scale closed mine waste facility which has been robustly monitored for a relatively long time in Nevada, USA. Results from the cover monitoring study provide an understanding of ET cover system performance for closure of other mine waste facilities, and offer guidance for ET cover system requirements in other arid regions.

Keywords evapotranspiration (ET) cover, store-and-release cover, cover performance, leach pad, mine closure

Introduction

The Barrick Goldstrike Mines Inc. (BGMI), located 60 kilometers (km) northwest of Elko in north-central Nevada, is a large open pit and underground gold mining operation. The AA Leach Pad (AA Pad) at BGMI operated from 1987 through 1999 and at the end of operation consisted of 55 million metric tonnes of run-of-mine leached ore. The facility covers approximately 100 hectares.

The AA Pad was reclaimed in 2000/2001 using a monolayer evapotranspiration (ET) cover to reduce net percolation, limit erosion, and support a robust plant community. The AA Pad ET cover design relies on approximately 1.2 meter thick fine-textured cover material layer overlying coarse leach ore material. The cover layer stores water during the wetter winter and spring months until ET, during the plant growing period (summer and fall), depletes the soil moisture by the following fall.

Cover systems evolve over time as the cover material develops in response to processes such as freeze/thaw cycles and root propagation and decay, which result in a decrease in soil bulk density and possibly the development of soil macro-pores (Benson et al. 2011). Additionally, the plant community and changes over time (species succession) and transpiration increases as the plant community becomes better developed and root depth and density increases.

BGMI has been evaluating water balance and vegetative performance data from the AA Pad cover system for eleven years. This paper presents long-term cover system performance data from the AA Pad including results from rooting surveys and in-situ hydraulic testing.

Materials and Methods

Site Characteristics

The climate at the site is semi-arid with hot summers and cold winters. Weather data has been collected since 1991 at the North Block weather station located approximately 5 km northwest of the AA Pad. Average annual daily temperature is about 9 °C. The majority of precipitation falls between December and May as snow. Annual precipitation is about 300 mm and average annual pan evaporation is about 1500 mm.

Vegetation in areas surrounding BGMI is primarily sagebrush-grass plant communities. Wyoming big sagebrush is the dominant woody sagebrush plants. Cool-season perennial grasses are the dominant herbaceous plants.
Cover System Hydrological Design

Potential borrow materials for the AA Pad cover system consisted of salvaged topsoil from the construction of the AA Pad and also salvaged topsoil materials or Tertiary-aged valley fill deposits (Tertiary Carlin Silt (TCS)) that were removed as overburden from the mine pit. The cover design was conceived and tested through the following process:

1. Laboratory Tests: Hydrologic property tests include dry bulk density, specific gravity, particle-size-distribution (PSD), saturated hydraulic conductivity ($K_{sat}$) and soil water characteristic curves (SWCC). To avoid the potential errors induced by gravel-correction, leach pad ores and potential cover materials were tested with the gravel portion included using large diameter columns (150 mm x 300 mm) at GeoSystems Analysis, Inc. in Tucson, Arizona.

2. One-dimensional Simulation: Several unsaturated numerical codes were evaluated for the cover design and SoilCover (Geo-Analysis 1997) was chosen for the simulations. SoilCover is a one-dimensional (1D), finite element package that models transient conditions. The model is based on Darcy’s and Fick’s Laws, which describe the flow of liquid water and water vapor, and Fourier’s law to describe conductive heat flow in the soil profile and soil/atmosphere boundary. The numerical analyses demonstrated that topsoil and TCS, have sufficient water holding capacity to be used for an ET cover. Additionally, the leach pad material was shown to be suitable as a capillary barrier layer when overlain by TCS/topsoil materials. The numerical analyses concluded that 90 cm of TCS/topsoil cover placed over the leach pad material would effectively minimize meteoric water percolating through the reclaimed leach pad (Zhan et al. 2000).

3. Two-dimensional Simulation: Since the AA Pad has long slopes, the real behavior of a cover system can be different than the idealized 1D model. A particular concern was moisture that builds up above the cover-leach ore interface could flow along the slope, and at a certain point the cover material could become wet enough to allow infiltration into the coarser leach ore. This point is called the Down Dip Limit (DDL) point. In order to examine whether or not the DDL would be reached, a two-dimensional (2D) simulation was conducted using the software HYDRUS2D (Simunek et al. 1999). The 2D simulated results demonstrated that in a normal precipitation year net percolation (infiltration minus ET) into the cover was close to zero and suction at the test slope since surface water run on makes vapor, and Fourier’s law to describe conductive heat flow in soil.

4. Pilot Field Test: Prior to full-scale cover installation a pilot study was conducted on a small-scale test cover plot placed on the AA Pad to examine the cover performance under simulated rainfall conditions. For this test, a 7 m x 7.5 m cover test plot with a thickness of 60 cm of TCS was constructed on the 3(H):1(V) east-facing slope of the AA Pad (Figure 1). After the cover was put in place, drip irrigation tubes were installed on the surface of the cover. Water content sensors (time-domain reflectometry, TDR) and matric potential sensors (heat dissipation sensors, HDS) were installed on the lower part of the test slope since surface water run on makes these areas more susceptible to net percolation. Performance testing simulated intermittent irrigation of approximately 227 cm of water (equal to about 7.6 years of precipitation) during the period of July to September 2000. The 1D numerical model was then calibrated to the observed data (Zhan et al. 2001b).

Fig. 1 will be inserted near here by the printer.

The water content of the cover reached as high as 0.30 cm$^3$/cm$^3$, during irrigation periods. Simulated volumetric water content corresponding to a wilting point of 4000 kPa, which is representative of desert plant communities in the Great Basin (Zhan et al. 2006), was 0.17 cm$^3$/cm$^3$, indicated a storage capacity of the cover equal to 0.13 cm$^3$/cm$^3$ (0.30 - 0.17 cm$^3$/cm$^3$). Consequently, a TCS cover thickness of 90 – 120 cm was predicted to be able to store 12 - 16 cm of water, independent of evaporation and lateral drainage. Based upon this analysis, the holding capacity of the cover would have sufficient volume to retain 3 continuous one-hundred year
storm events (approximately 24 cm of water), assuming half the precipitation runs off the cover. Therefore, the cover would operate as designed even under extreme precipitation conditions.

**Cover Engineering Design**

The engineering aspects associated with the closure of the AA Pad facility consisted of the following:

- Design of a permanent toe drain facility that would collect and isolate any water flux from the reclaimed heap leach pad over time.
- Preparation of a grading plan that would provide for adequate support and function of the soil cover, optimize revegetation and reclamation potential, minimize erosion risk and sediment yield, and provide a landform compatible with the natural landforms.
- Design of a drainage network on the cover surface which would safely and efficiently collect and remove surface runoff from the new landform, incorporating a natural looking configuration of drainages for the control of erosion and sediment yield (Figure 2).
- Balancing earthwork quantities and construction pathways to minimize construction costs and provide adequate space for the ET cover layer construction.
- Design of a perimeter storm drainage network capable of safely collecting and removing storm water runoff from the re-contoured heap surface.

Details about engineering design can be found in Myers et al. (2001). The geotechnical integrity of the cover system remains unchanged after having been in place for more than 10 years and experiencing numerous storms of varying intensity levels.

**Vegetation Design**

The AA Pad was seeded with a mix of grasses, forbs and shrubs (Table 1). The seed mix was based on 5 years of site specific research of vegetation data. In March of 2001, the seedbed was prepared and then broadcast seeded 18 kilograms per hectare of the selected seed mix and then harrowed a second time to lightly cover the seed. An organic mulch and tackifier were hydraulically applied over the entire unit at a rate of nine tonnes per hectare and 168 kilograms per hectare, respectively. Vegetation surveys to assess the resultant plant cover and species distribution on the AA Pad have been performed annually from 2001 to 2011.

**Cover Monitoring Instrumentation**

In different areas on the facility, the cover is composed of different materials of different thicknesses, with variable slope positions, solar aspects, and proximity to drainage channels. Cover system performance monitoring systems were installed between 2001 and 2005 on the AA Pad. Fourteen monitoring stations were located along three transects (East, West, and South, Figure 2), with six, five, and three stations, respectively. At each transect, sensor stations were located near the crest, mid-slope, and foot-slope of the AA Pad, and in addition, adjacent to stormwater runoff channels at the East transect. Instruments included Heat Dissipation Sensors (HDS, Campbell Scientific Inc., Logan, UT) to measure matric potential and temperature, Time Domain Reflectometry (TDR, Campbell Scientific Inc., Logan, UT), or capacitance (ECH2O, Decagon Inc., Pullman, WA) sensors to measure water content. Schematic diagrams showing sensor installation are shown on Figure 3.

**Rooting Survey and In-Situ Hydraulic Characterization**

The cover system performance monitoring stations were decommissioned in mid-October 2012. In conjunction with the decommissioning of the cover monitoring stations, in-situ testing of cover material Ksat and plant rooting surveys in the cover and leach ore materials were completed near the three monitoring transects. Two trenches, one upslope (A) and one downslope (B), were excavated at each of the three transects and two additional trenches were excavated adjacent to the East transect stormwater runoff channel sensor locations (D-A and D-B) as shown on Figure 2. At each trench, Ksat tests were conducted at two depths using a Woodings
infiltrometer (Soil Measurement Systems, Tucson, AZ) and soil $K_{sat}$ calculated using the methods described in Wooding (1968).

Root surveys were completed in triplicate at each of the eight trenches. Root size and density were determined according to Schoeneberger et al. (2002), with density and size rankings modified slightly to account for the arid terrain and sparse vegetation. Across the wall of each trench three 10 cm by 10 cm areas were examined at six depths, three in cover and three in the leach ore to the maximum trench depth, for a total of 18 measurements per trench. Rankings assigned for root density and root size are provided in Table 2.

**Calculation of Net Percolation Flux**

Net percolation flux of meteoric water near the cover-leach ore contact was estimated at each monitoring station by calculating the 1D vertical flux from Darcy’s Law for steady-state equilibrium as modified by Buckingham (1907) for unsaturated flow and van Genuchten’s (1980) analytical solution to Mualem’s (1976) theoretical model of the relationship between unsaturated hydraulic conductivity and matric potential. Flux rates were calculated from matric potential data and the measured hydraulic gradient between the two deepest HDS located at each station, together with van Genuchten parameters determined from SWWC, $K_{sat}$ and unsaturated hydraulic conductivity values measured in the laboratory. Net percolation flux rates calculated in this manner are referred to as matric-potential-based (MPB)-calculated flux.

Net percolation flux rates were also estimated from AA Pad drain-down flow data. Since closure, the AA Pad has been draining the residual solution remaining from the heap leach operations. Drain-down flow rate data have been collected on a bimonthly or monthly basis from 2002 through 2009 and approximately quarterly since January 2010. Draindown is characterized by slowly decreasing flow rates with annual spikes in the flow rate correlated to net percolation into the AP Pad from spring melt. Assuming that the drain-down flow rates observed in (the driest month of) October, approximate drainage rates solely from the residual heap leach solution (baseflow), draindown flow rates that exceed baseflow should approximate the area-averaged net percolation rate through the AA Pad cover system.

**Results**

**Precipitation**

Precipitation totals over the monitoring period from water year (WY, Oct 1 through September 30) 2002 to WY 2012 ranged from 201 to 493 mm, averaging 332 mm, 16 mm higher than the 316 mm long-term average (Figure 4). WYs were classified into average, wet, or dry years by defining a wet year as one with a WY precipitation total greater than one standard deviation (86 mm) above the long-term average, and a dry year as one with a total less than one standard deviation below the average. WYs 2005, 2006 and 2011 were wet years, WY 2008 was a dry year, and all other WYs were average years.

**Vegetation**

AA Pad vegetation survey data indicates that plant succession is progressing in a positive direction, and the AA Pad vegetation appears to be stable and self-sustaining, as well as resistant to erosion. Total plant cover in 2011 was 52.1% with 44.4% being derived from perennial species (Figure 5). By comparison the reference area only displayed 19.1% perennial cover out of 58.4% total plant cover. An example of the exemplary status of this reclamation effort is the 5.6% composition contributed by bitterbrush (Purshia tridentata), an extremely important, but difficult to establish component of the northern Nevada rangeland.

**Water Content Data**

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An example of typical water content sensor response at the West and South transect stations, and the East transect stations are presented on Figure 6 and Figure 7, respectively. Wetter conditions were observed at most monitoring stations during and following significant rainfall and snowmelt events in late fall, winter, and early spring; and drier conditions were observed during periods of decreased precipitation and high ET demand in late spring, summer and early fall. The West and South transect stations showed relatively dry conditions throughout average precipitation WYs 2003, 2007 through 2010, and 2012, indicating that the cover material in these areas is able to store and release most, if not all, infiltrating precipitation during WYs with average precipitation. Matric potential data showed similar wetting and drying trends as the water content data (matric potential data not shown). During wet WYs (e.g. 2005, 2006, and 2011) the measured water content and matric potential in the underlying leach ore showed relatively wet conditions, indicating that the storage capacity of the cover material had been exceeded and water percolated into the leach ore. The East transect stations generally showed increased water content at all depths each year between late February and early April, indicating that water is percolating to the depth of the leach ore sensor during all WYs. Nonetheless, the leach ore water content and matric potentials in the East transect stations also dried out more during the late summer and fall dry season indicating the ET depth was deep in the East transect area. These data support a conceptual model wherein, during WYs with average precipitation, the cover material stores and releases most if not all of the infiltrating water back into the atmosphere via ET and during wet WYs water years some water percolates into the leach ore material. In general, the maximum observed water content decreased over time at all transects, indicating greater cover system efficiency as vegetation became established.

**Fig. 6 will be inserted near here by the printer**

**Fig. 7 will be inserted near here by the printer**

**Drain-down Data**

AA Pad drain-down data generally showed seasonal increases in drainage rates in response to spring snowmelt (March-May) followed by declining rates over the summer and fall months. Figure 8 shows the average difference between the baseflow rate and the increased drainage rates in response to spring melt was 3.2 mm/yr (0.94 percent of precipitation) from October 2002 to October 2012.

Drain-down rates above estimated base-flow rates were observed most significantly in response to wet WYs 2005 and 2006; elevated rates persisted through WY 2007 before returning to estimated base-flow rates midway through dry WY 2008. By comparison, increased drain-down rates during wet WY 2011 were not as elevated as WY 2005 or 2006 flow rates and flow rates returned to estimated base-flow conditions during WY 2012. The reduced drain-down response to wet WY 2011 relative to wet WYs 2005 and 2006 indicates that two successive wet WYs magnified the net infiltration passing through the cover system, and/or that the cover system performance has improved over time. The latter could be due to maturation of the vegetation on the cover material and changes in hydraulic properties over time.

**Fig. 8 will be inserted near here by the printer**

**Decommissioning Rooting Survey**

For all trenches, root density generally decreased with depth, though a trend of increasing root density with depth was observed in the leach ore at the East transect trenches and may be a result of wetter conditions within the leach or at the East transect (Figure 9). Roots were typically seen at the maximum depth in each trench, indicating that at AA Pad water within the top meter or more of the leach ore is accessible by vegetation, as supported by leach ore drying in the summer.

The greatest leach ore root density was observed in the East transect trenches which also agrees with the observed higher density of deeper rooting shrubs at the East transect compared to other transects (Figure 4). The thicker cover material but shallower root density at the West transect trenches also agrees with the observed greater vegetation ground cover of predominately forbs and grasses at the West Transect.

**Fig. 9 will be inserted near here by the printer**

*In–Situ Hydraulic Characterization*
Mean surface $K_{sat}$ was similar across transects while at the 90 cm depth the mean $K_{sat}$ values ranged over an order of magnitude (Table 3). Mean $K_{sat}$ values at the West and East transects were approximately 5 times greater than the previous laboratory measured $K_{sat}$ values assigned for estimates of net flux (as described in the next section); $K_{sat}$ values for the South transect were 10 times greater. The larger in-situ measured $K_{sat}$ values is most likely from soil development processes such as freeze/thaw cycles and root propagation and decay that result in a decrease in soil bulk density and possibly the development of soil macro-pores (Benson et al. 2007).

**Estimates of Net Flux**

The MPB-calculated net percolation flux estimates indicate that the majority of net percolation occurred in wet WYs 2005, 2006, and 2011; whereas during average WYs, near-zero MPB-calculated net percolation values were calculated at most stations. Stations near stormwater runoff channels recorded the highest MPB-calculated flux rates of all the AA Pad stations. Weighting the MPB-calculated net percolation flux with respect to the amount of surface area on the AA Pad occupied by each monitoring station slope position (crest, mid-slope, foot-slope, and channels) results in an annual net percolation estimate of approximately 2.2 mm/yr (0.63 percent of precipitation) (Table 4).

The weighted average MPB-calculated net percolation estimate is less than the net percolation estimated from the drain-down data. A possible reason for this difference may be that actual net flux beneath the channels is higher than calculated since the monitoring sensors were not directly located below the drainage channel(s) and/or from the sensor upper measurement (wet-end) limit being exceeded during winter/spring precipitation and snowmelt conditions. Channel conditions may, in fact, be wetter than measured and greater rates of net percolation may occur. Additional reasons for the difference between MPB-calculated net flux and drain down data estimated net percolation may be the occurrence of macro-pore flow during large wetting events (e.g. snowmelt, high intensity precipitation) that is not detected with point measurements made by the matric potential sensors and error associated with the MPB flux model assumption of uniform flow. Nonetheless, the average channel station MPB-calculated flux was 5.5X the average MPB-calculated flux for the crest, mid-slope and foot-slope stations, within range of drainage flux to inter-drainage flux values that others have reported (Flint and Flint 2007; Scanlon 1999).

MPB-calculated net flux at the East and West transects was also estimated using the mean in-situ measured cover material $K_{sat}$ determined from the decommissioning study (Table 3). The mean in-situ $K_{sat}$ value for the East transect was 3.5X greater ($4.6\times10^{-4}$ cm/s) and for the West transect was 4.5X greater ($6.8\times10^{-4}$ cm/s) than the original laboratory derived $K_{sat}$ value ($1.30\times10^{-4}$ cm/s and $1.52\times10^{-4}$ cm/s, respectively) used in the above net percolation calculations. The South transect was excluded from this analysis because MPB-calculated net flux at the South transect only uses sensors located in the leach ore material.

Increasing the cover material $K_{sat}$ to the measured in-situ $K_{sat}$ values reduced the average annual estimated flux at the East transect from 5.6 mm to 3.0 mm (1.66 to 0.88 percent of precipitation) and at the West transect from 2.1 mm to 1.8 mm (0.62 to 0.54 percent of precipitation). Increasing the cover material $K_{sat}$ reduced the area-weighted average MPB-calculated net flux estimate to 1.5 mm/yr (Table 4). At both transects, the decrease in MPB-calculated net flux is due to a predicted increase in upward flux during periods of cover material drying in late summer and fall. While an increased cover material $K_{sat}$ would be expected to increase the rate of downward water movement within the cover during precipitation and snowmelt events, the increased downward flux in the cover is negated by less resistance to upward flux when hydraulic gradients are upward. Average annual estimated flux at the East transect is comparable to the West transect even though greater percolation into the leach ore is observed at the East transect during average water years (Figures 6 and 7), indicating that deep rooting vegetation (i.e. shrubs) access water that has percolated beyond the cover system.

Changes in cover material $K_{sat}$ would occur gradually over time and not a single point in time as applied here. As a result, the estimated decrease in MPB-calculated net flux with increased cover $K_{sat}$ would likely be less. This is possibly corroborated by the decrease in drain down flow response to wet WY 2011 in comparison to wet WYs 2005 and 2006. It is worth noting that variability between in-situ $K_{sat}$ measurements within transects was over an order of magnitude. Consequently, spatial variability in hydraulic properties between monitoring stations also likely affected matric potential sensor response and estimated net percolation flux estimates.
Conclusions

Eleven years of cover monitoring data at AA Pad indicate that the cover is limiting average annual net percolation flux through the cover to 2.2 mm/yr (0.63% of precipitation), based on the area weighted average MPB-calculated flux. Estimated average annual flux from seasonal increases in AA Pad drain-down rates in response to spring melt are slightly higher than the MPB-calculated flux, being 3.2 mm/yr (0.94% of precipitation). Considering the small difference, it is reasonable to conclude that net percolation through the cover is less than 1% of the precipitation.

Eleven years of vegetation surveys indicate that plant succession is progressing in a positive direction and plants within these areas are self-sustaining and reclaimed sites appear at least as stable and resistant to erosion as nearby, undisturbed areas.

Acknowledgements

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References


Mualem Y (1976) A new model for predicting the hydraulic conductivity of unsaturated porous pedia.

Water Resour Res. 12:513-522


**Fig. Captions**

Fig. 1 AA Leach Pad 2000 pilot field test: irrigated area (left) and data acquisition system (right)

Fig. 2 AA Leach Pad monitoring site and test trench locations

Fig. 3 Installation schematic for cover performance monitoring stations

Fig. 4 Water year, long-term mean, and long-term mean +/- one standard deviation precipitation

Fig. 5 AA Leach Pad perennial plant cover (2001-2011, no survey in 2009 and 2010)

Fig. 6 Volumetric water content: West 2 (topsoil cover, mid-slope)

Fig. 7 Volumetric water content: East 3 (Carlin cover, mid-slope)

Fig. 8 Predicted and measured drain-down from AA Leach Pad

Fig. 9 Root density survey results
### Table 1: Species in the seed mix

<table>
<thead>
<tr>
<th>Species in the seed mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Basin Wildrye</td>
</tr>
<tr>
<td>Bluebunch Wheatgrass</td>
</tr>
<tr>
<td>Crested Wheatgrass</td>
</tr>
<tr>
<td>Thickspike Wheatgrass</td>
</tr>
<tr>
<td>Lewis Flax</td>
</tr>
<tr>
<td>Indian Ricegrass</td>
</tr>
<tr>
<td>Palmer Penstemon</td>
</tr>
<tr>
<td>Fourwing Saltbrush</td>
</tr>
<tr>
<td>Big Bluegrass</td>
</tr>
<tr>
<td>Sandberg Bluegrass</td>
</tr>
<tr>
<td>Small Burnet</td>
</tr>
<tr>
<td>Forage Kochia</td>
</tr>
<tr>
<td>Winterfat</td>
</tr>
<tr>
<td>Wyoming Big Sagebrush</td>
</tr>
<tr>
<td>Regreen</td>
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### Table 2: Root density and root size rankings

<table>
<thead>
<tr>
<th>Root Density</th>
<th>Root Size</th>
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<tr>
<td>0</td>
<td>none (0 roots)</td>
</tr>
<tr>
<td>1</td>
<td>very fine (vf)</td>
</tr>
<tr>
<td>2</td>
<td>few (4-6 roots)</td>
</tr>
<tr>
<td>3</td>
<td>medium (m)</td>
</tr>
<tr>
<td>4</td>
<td>coarse (c)</td>
</tr>
<tr>
<td>5</td>
<td>very coarse (vc)</td>
</tr>
<tr>
<td>6</td>
<td>greater than 10 mm diameter</td>
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### Table 3: In-situ measured cover material saturated hydraulic conductivity

<table>
<thead>
<tr>
<th>Sampling Location</th>
<th>Saturated Hydraulic Conductivity (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
</tr>
<tr>
<td>West-A</td>
<td>3.6E-03</td>
</tr>
<tr>
<td>West-B</td>
<td>1.5E-04</td>
</tr>
<tr>
<td>West Mean</td>
<td>7.4E-04</td>
</tr>
<tr>
<td>South-A</td>
<td>7.7E-04</td>
</tr>
<tr>
<td>South-B</td>
<td>1.4E-04</td>
</tr>
<tr>
<td>South Mean</td>
<td>3.3E-04</td>
</tr>
<tr>
<td>East-A</td>
<td>1.3E-03</td>
</tr>
<tr>
<td>East-B</td>
<td>2.5E-04</td>
</tr>
<tr>
<td>East Mean</td>
<td>5.6E-04</td>
</tr>
<tr>
<td>East-D-A</td>
<td>4.7E-05</td>
</tr>
<tr>
<td>East-D-B</td>
<td>1.5E-03</td>
</tr>
<tr>
<td>East-D Mean</td>
<td>2.6E-04</td>
</tr>
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### Table 4: Area-weighted MPB-calculated flush using laboratory and in-situ measured cover material $K_{sat}$

<table>
<thead>
<tr>
<th>Slope Position</th>
<th>Area (hectares)</th>
<th>Laboratory $K_{sat}$</th>
<th>In-Situ $K_{sat}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crest</td>
<td>16.4</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Mid-slope</td>
<td>66.3</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Foot-slope</td>
<td>8.1</td>
<td>0.2</td>
<td>-0.1</td>
</tr>
<tr>
<td>Channels</td>
<td>4.8</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>95.6</td>
<td>2.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Figure

Legend:

- **Data Logger**
- **Water Content Probe**
- **Heat Dissipation Sensor (HDS)**

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

Carlin Silt (East and South) or Top Soil (West) Cover

Leach Ore

Not to Scale
Figure

Percent Perennial Cover

Year: 2001 - 2011

- 2001: 9.7%
- 2002: 24.6%
- 2003: 40.3%
- 2004: 43.3%
- 2005: 45.3%
- 2006: 41.3%
- 2007: 38.6%
- 2008: 37.6%
- 2011: 44.4%
Cover Thickness: 134 cm
Cover Thickness 117 cm

Water Content (cm³/cm³)

Daily Precipitation (cm)

Date

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

30 cm 77 cm 107 cm 127 cm (leached ore) Precipitation