Assessment of Store-and-Release Cover for Questa Tailings Facility, New Mexico

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ABSTRACT: A test plot study has been initiated to study the performance of a store-and-release cover consisting of alluvial soil over tailings proposed for final closure of a large tailings facility in New Mexico. The test plot study consists of two closed lysimeters covered with 0.23m (9") and 0.60m (24") of alluvial soil (silty gravel) over backfilled tailings and an instrumented deep *in-situ* tailings profile with a 0.28m (11") alluvial cover with existing grass/shrub vegetation. All test plots were instrumented with temperature/suction sensors and moisture content sensors to monitor moisture movement in the cover/tailings profile. The lysimeters are free-draining and outflow is collected and monitored continuously using a tipping bucket. The lowest rate of net infiltration (20mm or 6% of total precipitation) during the first year of monitoring was observed in the deep *in-situ* cover/tailings profile. Net infiltration into the unvegetated lysimeter test plots were 55.9mm (17.3%) for the 0.23m alluvial cover and 117mm (36%) for the 0.60m alluvial cover. Initial calibration of a soil atmosphere model (SoilCover) to the test plot data suggested that the lower rates of net infiltration into the *in-situ* profile are a result of (i) higher evapotranspiration due to the presence of vegetation and (ii) lower vertical hydraulic conductivity of the *in-situ* tailings (relative to the backfilled tailings in the closed lysimeters). The observed rates of net infiltration for the unvegetated, backfilled lysimeters may therefore significantly overestimate cover fluxes for long-term (post-closure) conditions. The calibrated model should be used to predict cover performance for a range of climate conditions (e.g. wet year *vs* dry year) and cover design parameters (e.g. cover thickness).

1 INTRODUCTION

Molycorp Inc. owns and operates a large tailings facility located near the village of Questa, New Mexico (Figure 1). Over the last 33 years a total of nearly 100 million tons of tailings from the Questa Molybdenum Mine have been discharged into this facility covering a total surface area of about 260 ha (640 acres) (as of 1997). The tailings originate from a hydrothermally altered molybdenum porphyry deposit of volcanic origin and are produced at the Questa mine, located 8 km to the east of the Questa tailings facility.

Final closure of the facility will require covering of the tailings with locally available alluvial soils (silty gravel) after final closure of the facility (RGC, 1998). This soil layer would prevent erosion of the tailings (primarily by wind), provide a growth medium for revegetation and, in conjunction with the underlying tailings, represent a water storage (or "store-and-release") cover that would reduce infiltration into the deeper tailings profile.

This test plot study focuses on the function of the proposed alluvial cover to control net infiltration and ultimately seepage from the tailings impoundments. A store-and-release cover typically consists of a well-graded soil layer (or multiple soil layers) that stores precipitation during wet periods and releases the moisture back to the atmosphere via evapotranspiration during dry periods. The net effect is a significant reduction, or elimination, of net percolation (also called "cover flux"), and ultimately seepage from the tailings impoundment. The semi-arid climate conditions experienced at Questa, New Mexico favor the use of the store-and-release cover over the more conventional water barrier ("low permeability") cover. While the dry climate generally improves the performance of the store-and-release cover (due to high rates of evaporation coupled with low precipitation) it often compromises the performance of a water barrier cover due to problems with

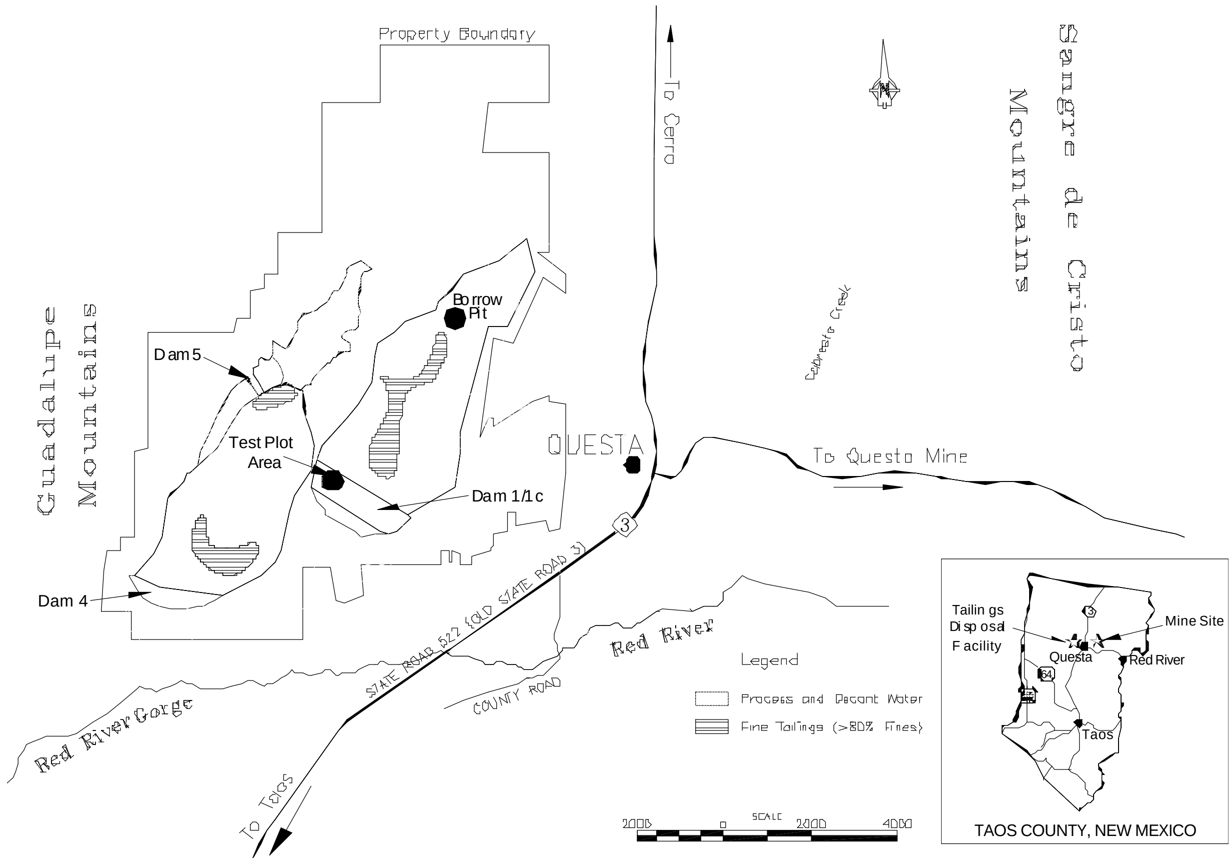

Figure 1. Location Map of Questa Tailings Facility

desiccation (e.g. Swanson et al., 1997; Bews et al., 1997). Store-and-release covers have been designed for several mine sites in arid or semi-arid climates (e.g. PTI and WESTEC, 1996; GSM, 1995; and O'Kane et al., 1998).

The main advantages of the store-and-release cover compared to other alternatives considered (low permeability and capillary barrier covers) are:

- a store-and-release cover will require the least long-term maintenance and has the lowest potential for long-term degradation (and ultimately failure);
- the effectiveness of a store-and-release cover is expected to increase in time as the vegetation matures to the desired climax vegetation (e.g. sagebrush and juniper); and
- the proposed store-and-release cover can be implemented for a fraction of the cost of more complex engineered cover types.

Molycorp has implemented a test plot study at the Questa tailings facility to evaluate net infiltration through the proposed store-and-release cover (RGC, 2000a). The test plot study was initiated to collect site-specific data of cover performance for the purpose of final design. Specifically, the test plot study was designed to meet the following objectives:

- measure climatic conditions at the site;
- measure *in-situ* material properties (characteristic curves); and
- calibrate a soil-atmosphere model in order to predict net infiltration.

It is important to recognize that the primary objective of the test plot study was not to measure actual cover fluxes *per se* but instead, to calibrate a soil-atmosphere model for known (measured) boundary conditions. The ultimate goal is to use the calibrated soil-atmosphere model to predict with a high degree of confidence the performance of the storage cover for conditions relevant to final closure (i.e. deep, unsaturated tailings profile; mature vegetation; range of climatic conditions). These final closure conditions cannot, of themselves, be duplicated in a field trial of only a few years, but instead have to be simulated.

2 SITE DESCRIPTION

The Questa tailings facility is located west of the village of Questa in northern New Mexico (Figure 1). The tailings facility lies in an alluvial plain at an elevation of about 2320m amsl, bordered by the Sangre de Cristo Mountains to the east and the Guadalupe Mountains to the west. The tailings were impounded in two deeply incised valleys (so-called "arroyos") behind two earth fill dams (Dams 1/1C and Dam 4, respectively). Tailings are currently discharged behind Dam 4.

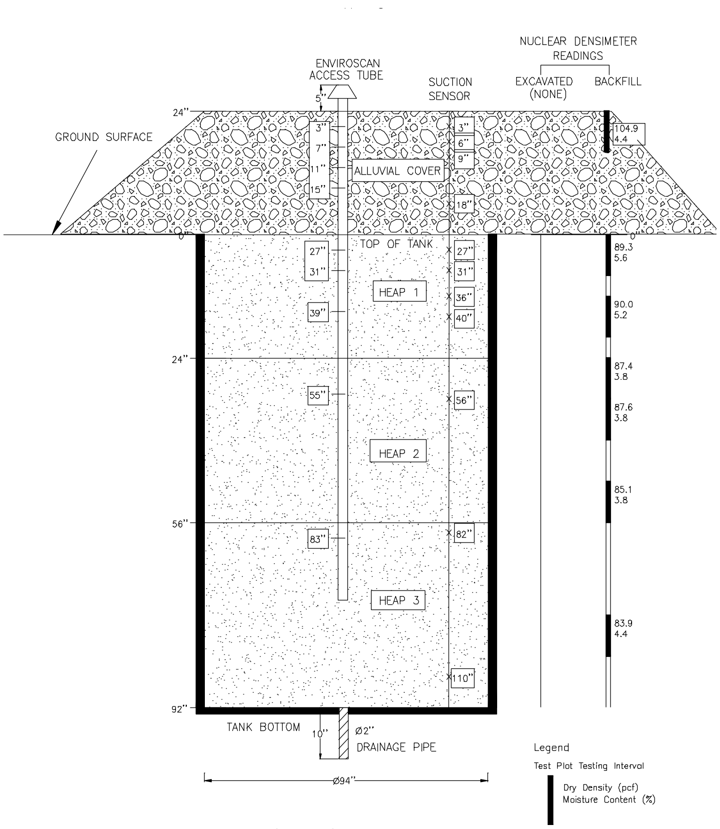

Figure 2. As-Built profile of test plot TP-3.

The test plots for this study were constructed on the tailings beach between Dam 1 and Dam 1C (Figure 1). Dam 1 was constructed in 1966 as an earthfill dam across an arroyo and was raised by downstream construction using earthfill. In 1975, "Old" Dam 1C was constructed of cycloned sand 200m upstream of Dam 1. In 1981 "New" Dam 1C was constructed at its present location (Figure 1). This 'new' dam replaces the old dam, which is contained within the tailings deposited behind "New" Dam 1C (see Wels et al., 2001 for more details on the discharge history).

A detailed physical and geochemical characterization of the Questa tailings was carried out as part of the development of the Revised Closure Plan for this facility (RGC, 1998). Briefly, the Questa tailings are geochemically similar mixtures of aplite and andesite tailings with low-moderate sulfide content (0.5–1.5% pyrite). The predominantly andesitic tailings have higher sulfide-sulfur contents and a higher potential to generate acid than the slimes tailings or aplite tailings. Despite the oxidation potential of sulfide minerals, the Questa tailings are currently not acid generating. The surface tailings, which have been most susceptible to oxidation processes, have remained grey in color and are consistently circum-neutral with respect to paste pH. The field and laboratory data suggest that the buffering capacity of the tailings is sufficient to maintain circum-neutral pH in the tailings pore water (Wels et al., 2000).

A total of 32 tailings samples were analysed for standard grain size analyses (ASTM D422) to characterize the spatial distribution of the tailings at the surface of the impoundments according to size fraction. The tailings were subdivided into three classes:

i. coarse tailings with <50% fines content (where fines constitute silt and clay sized particles with a grain diameter smaller than 0.075 mm (# 200 mesh));
ii. intermediate tailings with 50%< fines content <80%; and
iii. fine tailings with >80% fines.

This survey suggested that the coarse tailings represent about 2/3 of the total surface area. The fine tailings comprise only about 12% of the present tailings surface area (see Wels et al., 2001 for additional details).

The climate of the study area is semi-arid. Annual precipitation at nearby Cerro averages about 310mm (12.2 inches) with much of this precipitation occurring as summer thundershowers (on average 43% of total precipitation occurs from July to September). The summers are moderately warm with maximum daily temperatures around 27°C (81°F). The winters are long with temperatures dropping below freezing almost every night from October through to April. However, typically clear skies bring sunshine during most days with temperatures rising to above the freezing point. During the winter much of the precipitation falls as snow. Nevertheless, a significant snow pack rarely develops due to intermittent snowmelt and/or sublimation. Based on frost data collected by the U.S. Weather Bureau at Cerro a growing season of 120 days is average for the study area. As expected for this semi-arid climate, the potential evaporation rates far exceed precipitation rates during all months on record. The annual pan evaporation is estimated to be about 1715mm (67.5 inches).

3 DESIGN OF TEST PLOT STUDY

The test plot study was designed to evaluate factors controlling the performance of the cover and the net infiltration to the tailings, i.e. material properties, climate conditions and cover thickness (RGC, 2000a). A total of three test plots were constructed in the beach area between Dam 1 and Dam 1C of the Questa tailings facility (Figure 1). This tailings area has been covered for about 25 years, which allowed the establishment of a mature grass/shrub vegetation on the cover material. An initial reconnaissance survey indicated that the interim cover placed historically in this area was quite variable (ranging in thickness from 0.23m (9") to greater than 0.60m (24")). The test plot location finally selected (in the eastern portion, see Figure 1) was deemed most representative of the requirements for the deep *in-situ* test plot TP-1, i.e. an existing shallow alluvial cover with mature grass/brush vegetation.

The three test plots were constructed and instrumented to measure the performance of three different combinations of cover thickness and vegetation development:

Test Plot #1: Existing 0.28m (11”) thick alluvial cover with mature grass/shrub vegetation overlying *in-situ* sandy tailings (very deep tailings profile);

Test Plot #2: 0.23m (9”) thick alluvial cover with no vegetation overlying back-filled sandy tailings (~2.5 m deep tailings profile); and

Test Plot #3: 0.60m (24”) thick alluvial cover with no vegetation overlying back-filled sandy tailings (~2.5 m deep tailings profile).

Test plot #1 is most representative of post-closure steady-state conditions, i.e. with mature vegetation established on the alluvial cover overlying undisturbed, hydraulically placed tailings. This test plot is designed as an open system, with the monitoring instrumentation was installed into the existing cover and tailings profile (without prior excavation). Any excavation of the cover and tailings profile would destroy the root system of the vegetation, which is considered a vital component of this cover system, as well as the ‘natural’ soil structure and density of the hydraulically placed tailings. Test plot #1 will be used to calibrate the soil-atmosphere model (including effects of vegetation on evapotranspiration) against measured changes in soil moisture and soil suction over time. The calibrated soil-atmosphere model of test plot #1 will be used to predict the net flux through a mature cover system for post-closure steady-state conditions.

Test plots #2 and #3 represent free-draining “lysimeter plots”, in which the rate of net percolation through the cover and shallow tailings profile is monitored directly and leachate is collected at the base of the lysimeter (Figure 2). Test plots #2 and #3 will be used to assess the influence of cover thickness on net percolation (initially without the influence of transpiration by plants). Both test plots will allow calibration of the soil-atmosphere model not only against observed suction/moisture content in the profile but also against measured net fluxes observed discharging at the base of the lysimeters.

Two sets of sensors were installed in the three test plot profiles. *In-situ* temperature and soil matric suction is measured using a thermal conductivity type sensor CS 229 (Campbell Scientific, 1998). The volumetric moisture content is measured indirectly using the capacitor-type sensors Enviroscan™ distributed by SENTEK Environmental Technologies, Adelaide, Australia. (SENTEK, 1997).

3.1 *Construction and Instrumentation*

The construction and instrumentation varied between the deep, relatively undisturbed profile (test plot TP-1) and the closed lysimeters (test plots TP-2 and TP-3). For test plot TP-1 an access ditch was excavated along one side of the test plot to a depth of approximately 2.7m. The access ditch was used to determine *in-situ* material properties, collect representative samples, and to provide access to the revegetated, undisturbed tailings profile for lateral installation of the suction-temperature sensors.

For construction of the lysimeter test plots TP-2 and TP-3, thick walled (19mm) HDPE tanks with a diameter of 2.4m and a height of 2.3m were used (Figure 2). For each test plot, a large pit was first excavated into the existing tailings profile, and the tailings logged, sampled and stockpiled. A lysimeter tank was then lowered into the excavation and backfilled with the stockpiled tailings. An attempt was made to reproduce the same layering and *in-situ* properties (moisture content and bulk density) observed during excavation. A 50mm diameter discharge pipe was installed at the base of the tank to allow free drainage. This discharge pipe connects to a manhole where outflow is monitored continuously using a tipping bucket and a data logger.

After backfilling the lysimeter and construction of the discharge/manhole system, the alluvial cover material was placed in a single lift without compaction using the backhoe. The alluvial cover was placed over a foot print area of about 6.0m x 6.0m, or about eight times the foot print area of the lysimeter in order to minimize boundary effects. The alluvial material used for cover construction on the lysimeter test plots (TP-2 and TP-3) was taken from a local borrow pit with alluvial soil deemed representative of the alluvial soils proposed for final cover of the tailings facility (see Figure 1 for location).

A fully automated meteorological station was set up in the test plot area to evaluate atmospheric boundary conditions for future numerical model calibration. The weather station consists of an all-weather rain gauge, relative humidity/temperature probe, wind sensor, and net radiometer. In addition, a Bowen Ratio system was installed to measure actual evapotranspiration. More details on the construction and instrumentation of the test plots are provided by Wels et al. (2001).

3.2 *Material Testing*

Representative samples of tailings and alluvial cover material were taken during construction of the test

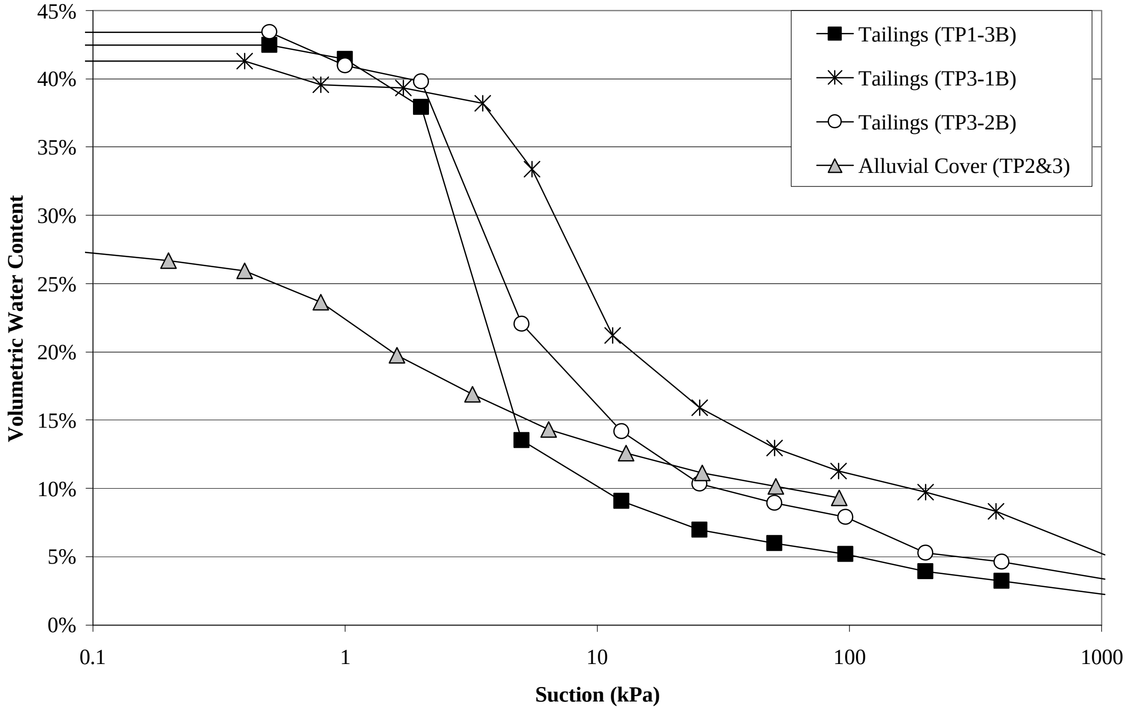

Figure 3. Soil Water Characteristic Curve for test plot samples.

plots and submitted for laboratory testing to determine hydraulic properties and soil water characteristic curves (see RGC, 2000b for details). The geotechnical characterization included grain size analysis, moisture content, standard proctor compaction, permeability, and soil water characteristics (i.e. moisture retention). The alluvial cover material represents a fairly well-graded silty/clayey gravel (GM-GC) with a fines content ranging from 7.8 to 10.9%. In contrast, the tailings encountered at the test plots represent a poorly graded silty sand (SM) with a fines content ranging from 12.4% to 48.2%. The tailings used for the test plot study are representative of the "coarse" tailings, which cover about 2/3 of the total tailings area at the Questa tailings facility.

Figure 3 shows the soil water characteristic curves (SWCC) determined for representative samples of the tailings and the alluvial cover material. The (coarse) tailings have a higher porosity and a steeper SWCC than the alluvial soil. The air entry value (AEV) of the tailings is slightly higher (~1 to 5 kPa) compared to that of the alluvial material (<1 kPa). The large range of particle sizes (from gravel to clay size) in the alluvial cover material is responsible for the low AEV and the gradual decline in moisture content with increase in suction (i.e. successive drainage of increasingly smaller pore spaces with increasing suction).

4 1ST YEAR MONITORING RESULTS

The monitoring results of the test plot study for the first year of monitoring (August 2000 – July 2001) are summarized in Table 1. The climate conditions for the first year of monitoring were typical for the region with a total precipitation of 323mm (12.7 inches) and potential evaporation of 1120mm (44.1 inches). Potential evaporation was calculated from local climate data, including daily average air temperature, relative humidity, net radiation, and wind speed (Penman, 1948).

Table 1. Summary of 1st year test plot monitoring.

	TP-1	TP-2	TP-3
Cumulative precipitation (mm)	--------- 322 ---------		
Cumulative Potential Evaporation (mm)	-------- 1120 --------		
Net Infiltration (mm)[1]	20.5	57.4	117.9

Notes:

1. Change in storage calculated from measured volumetric water content profiles

During the first year of monitoring no outflow was recorded at the two lysimeters. However, detailed measurements of volumetric water content allowed the calculation of net infiltration into the cover/tailings profile. This was done by integrating the volumetric water content profiles at the start and end of the first year of monitoring. The rates of net infiltration (precipitation minus actual evapotranspiration) ranged from 20.5mm (6.3% of precipitation) for TP-1 to 117.9mm (36.6% of precipitation) for TP-3. The net infiltration for test plot TP-2 was intermediate at 57.4mm (17.8% of precipitation). Note that the rate of net infiltration at the surface is still significantly higher than the rate of deep percolation (or "cover flux") into the deeper tailings profile, in other words the test plots are still wetting up and

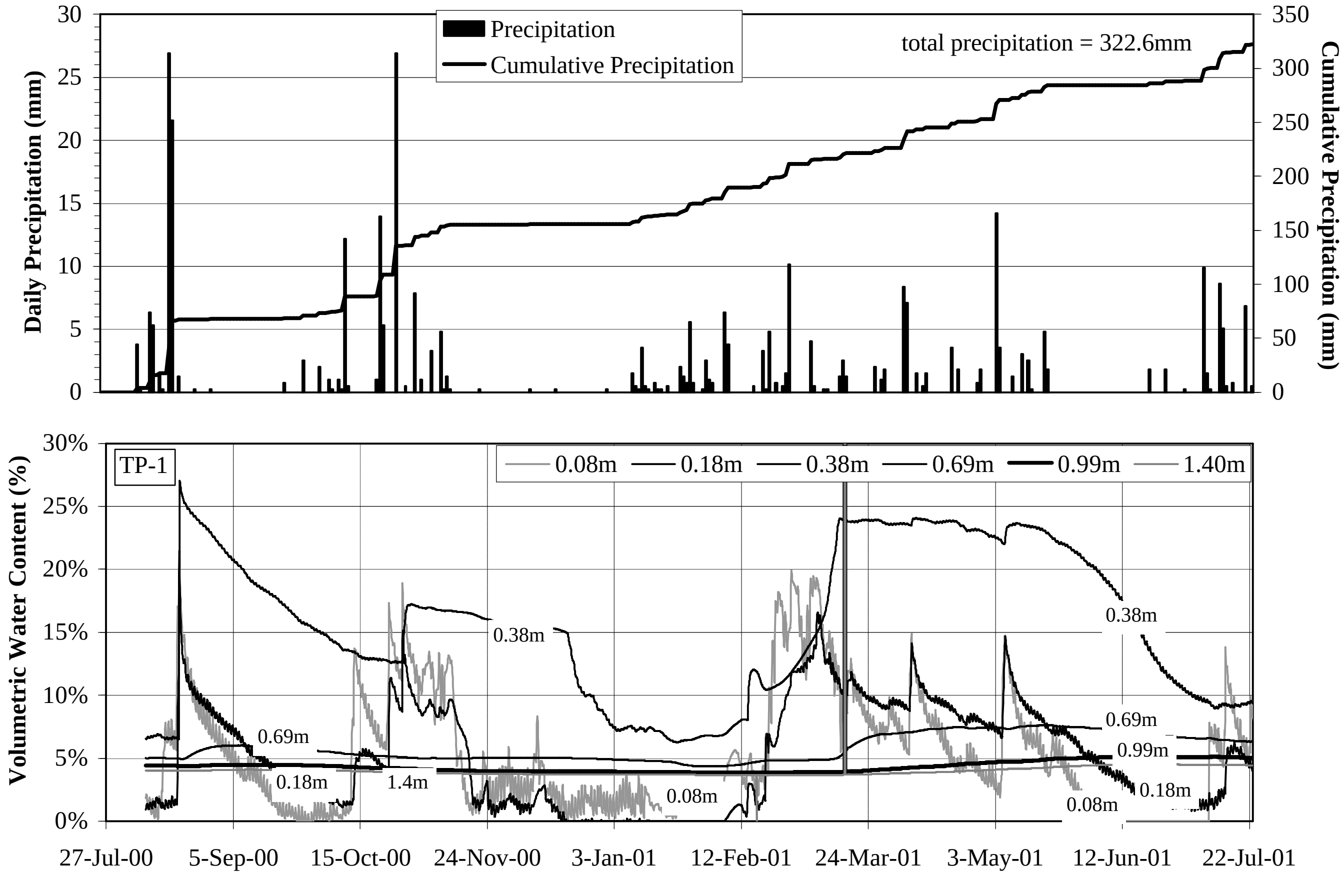

Figure 4. Time trend for Volumetric Water Content for selected depths in test plot TP-2, showing precipitation for comparison.

have not yet reached (pseudo) steady-state conditions. This is evident in the lack of outflow at the base of the two lysimeters. A good estimate of deep percolation will only be attainable after several years of monitoring, including direct measurements of lysimeter outflow over time.

Figure 4 shows the time trends of volumetric water content for the deep, undisturbed test plot profile (TP-1). The daily precipitation is also shown for comparison. The first significant wetting occurred after a heavy precipitation period in mid-August when 48mm (1.9 inches) of precipitation occurred in 2 days. In the near-surface layers (top 0.38m) of the cover/tailings profile the volumetric moisture contents exhibited a very rapid increase (during the rainfall period) followed by a gradual decline due to subsequent evapotranspiration and drainage. During the winter months (Nov 2000 – Feb 2001) the soils in the test plots froze to a depth of ~0.5-0.6m (RGC, 2001a). The freezing of the soil is clearly recognizable in Figure 3 by the sudden drop in the volumetric water content (the sensors measure only liquid water content).

A combination of thawing of the upper soil layers and precipitation during the early spring period resulted in renewed wetting of the upper cover/tailings profile (late February to early March, 2001). During the latter portion of the spring period the alluvial cover experienced repeated wetting and drying in response to precipitation events (see sensors at 0.07 and 0.18m depth, Figure 4). These wetting-drying cycles maintained very wet conditions in the uppermost layers of the *in-situ* tailings profile (e.g. at 0.38m depth); however, they did not result in significant wetting of the deeper tailings profile (>0.69m depth). Drier conditions prevailed between May and July 2001 resulting in drying of the alluvial cover and the upper layers of the tailings profile (Figure 4). By the end of the first year of monitoring the water content in the deeper tailings profile (>1.0m) still remained very close to the initial (residual) water content.

Figure 5 shows the time trends of volumetric water content for the two lysimeter test plots TP-2 (upper panel) and TP-3 (lower panel). The general seasonal pattern of moisture contents is similar to that observed in the *in-situ* profile of TP-1; however there are several important differences. First, the water contents in the lysimeter test plots (in particular in TP-3) did not show as fast a decline in water content during dry periods as observed in TP-1. This is a result of the absence of vegetation. In the unvegetated lysimeter test plots evaporation at the soil surface is the only removal mechanism of soil moisture. In contrast, the existing vegetation in TP-1 is able to remove soil moisture deeper from the soil profile by root uptake and plant transpiration in addition to evaporation. Second, the wetting front progressed

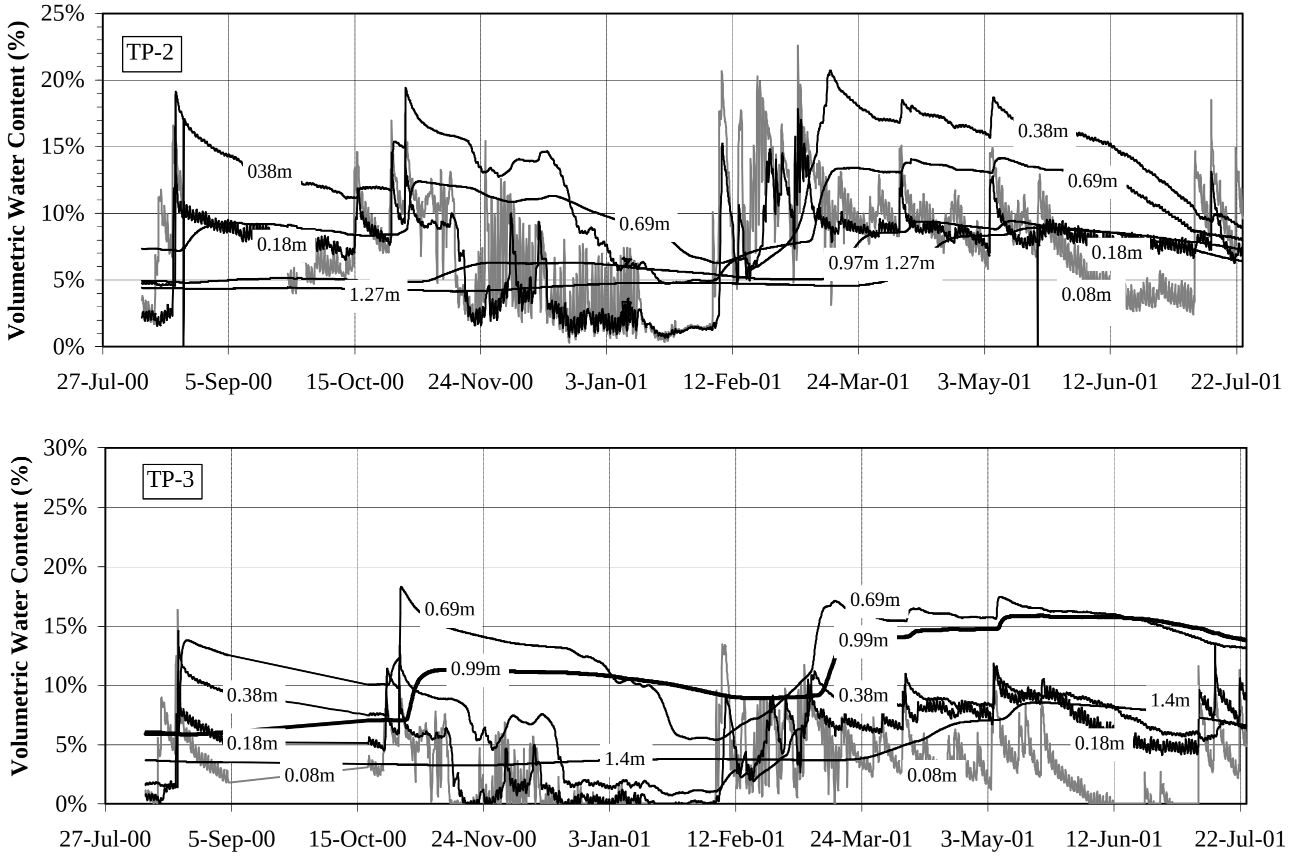

Figure 5. Time trend of Volumetric Water Content for selected depths in test plots TP-2 and TP-3.

much deeper into the tailings profile of the lysimeter plots compared to the deep *in-situ* tailings profile. For example, a clear increase in moisture content was observed in both lysimeters at around 1.25m in response to the spring rains compared to no significant response in TP-1 (compare Figures 4 and 5). The faster wetting of the lysimeter plots is believed to be a result of the loose structure of the backfilled tailings compared to the *in-situ* tailings profile, which is strongly layered due to hydraulic placement. The backfilling likely increased the vertical hydraulic conductivity of the tailings material (despite the similarity in bulk density). The increased supply of soil moisture in the upper profile (due to lack of plant transpiration) may have also contributed to the faster wetting in the two lysimeter test plots.

Figure 6 compares suction and moisture content profiles in all three test plots for selected dates during the first year of monitoring. The depth of the alluvial cover is shown in these profiles for reference. The suction and moisture content profiles clearly illustrate the deeper wetting that occurred in the lysimeter test plots TP-2 and TP-3 compared to in the *in-situ* profile TP-1. The volumetric moisture content in the alluvial cover was generally significantly lower than in the underlying tailings despite similar, if not lower, suction values (Figure 6). This is a result of the much coarser soil texture and hence lower porosity of the cover relative to the tailings (Figure 3). The lower porosity of the alluvial cover also results in a deeper wetting front for the case of a 0.60m thick cover (up to 1.4m wetting in TP-3) compared to the case of a 0.25m cover (~1.0m and < 0.7m in TP-2 and TP-1, respectively). These observations highlight the fact that the tailings have a much better storage capacity than the alluvial cover.

The volumetric water content values near the base of the lysimeters TP-2 and TP-3 started to show a small increase towards the end of the first year of monitoring (Figure 7 and 8). However, they are still much lower than the field capacity of the tailings. These observations are consistent with the lack of any outflow from the lysimeters recorded in the manhole. Based on the observed rates of net infiltration it may take another 1-2 runoff seasons (or more) before there will be any measurable discharge from the base of the lysimeters.

4.1 *Initial Soil Atmosphere Modeling*

The soil atmosphere model SoilCover (Geoanalysis 2000 Ltd., 2000) was used to simulate the transient soil moisture conditions in the tailings test plots. For each test plot, model runs were carried out using local climate data collected at the primary met station over the period of August 8, 2000 to February 19, 2001. Most of the initial calibration runs, however, focused on the period August 8 to October 8, 2000 to avoid complications with snow cover and soil

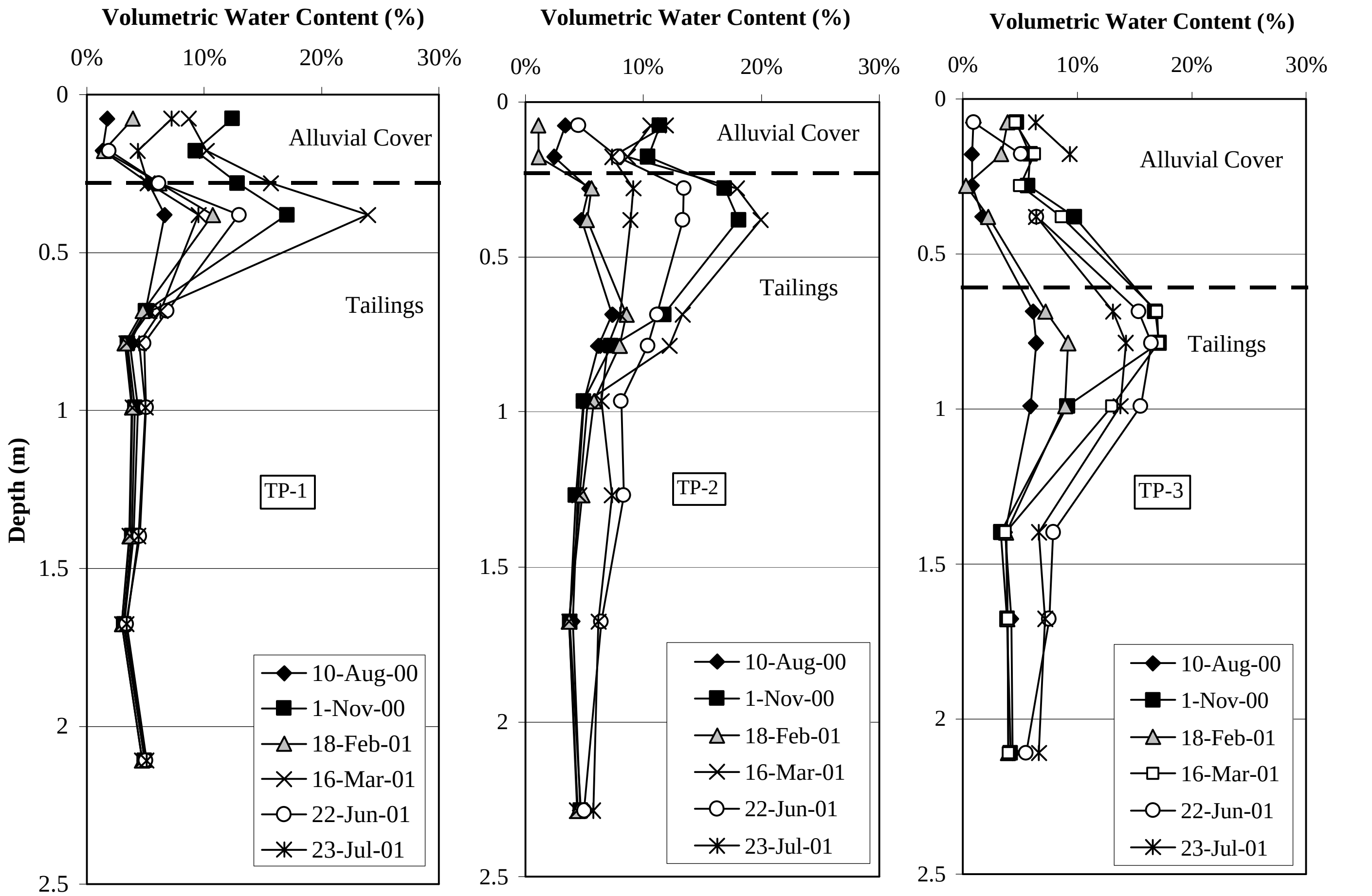

Figure 6. Volumetric Water Content profiles for TP-1, TP-2 and TP-3.

freezing. The goal of this initial calibration was to get a general agreement of the model predictions with observed trends in volumetric water content and soil suction.

For each test plot a SoilCover model was calibrated using a trial-and-error approach (RGC, 2001b). The model requires the input of both atmospheric data as well as material properties for the cover/tailings. In general, the climate data were well known (measured on site) and were used as fixed input to the model. The only exception was the potential evaporation (which is calculated internally by the model based on climate data). Initial calibration runs (using unadjusted climate data) suggested that SoilCover overpredicted actual evapotranspiration during days of high rainfall. This discrepancy is likely a result of the fact that SoilCover assumes rainfall to be uniformly distributed across a given day, whereas in reality heavy rain showers generally occur in the late afternoon or evening when potential ET rates are sharply declining. A much better fit with field measurements were obtained when assuming no evapotranspiration for days with precipitation greater than 5mm (0.2 inches).

In this initial calibration the emphasis was placed on varying the hydraulic conductivity of the material rather than on varying the SWCC. This approach was chosen because the SWCC data (from the lab and field) are considered more reliable than estimates of hydraulic conductivity (uncertainty in extrapolation of lab measurements to the field). Hence the SWCC used as input to the model were derived from the laboratory data and the *in-situ* measurements (RGC, 2001a). The key variable to be determined in the calibration process was the saturated hydraulic conductivity. In all cases, the initial estimates were taken from representative laboratory measurements. In subsequent analyses the initial guesses were adjusted to either increase or decrease the advance of the wetting front in the alluvial cover and/or tailings.

Figure 7 compares simulated and observed depth profiles of volumetric water content for selected dates in test plot TP-2. The hydraulic conductivity assumed for the "calibrated" model were $3.8*10^{-3}$ cm/s and $1.45*10^{-3}$ cm/s for the alluvial cover and underlying tailings, respectively. These calibrated values fall well within the range of Ksat values determined for these materials in the laboratory (RGC, 2001b). The match between observed and simulated suctions and in particular VWC is very good in light of the few numbers of parameters that had to be adjusted to obtain this fit.

TP-1 differs from TP-2 and TP-3 in that a grass/shrub vegetation is present. The influence of vegetation on net infiltration was simulated using the vegetation option in SoilCover. For modeling purposes it was assumed that plant transpiration oc-

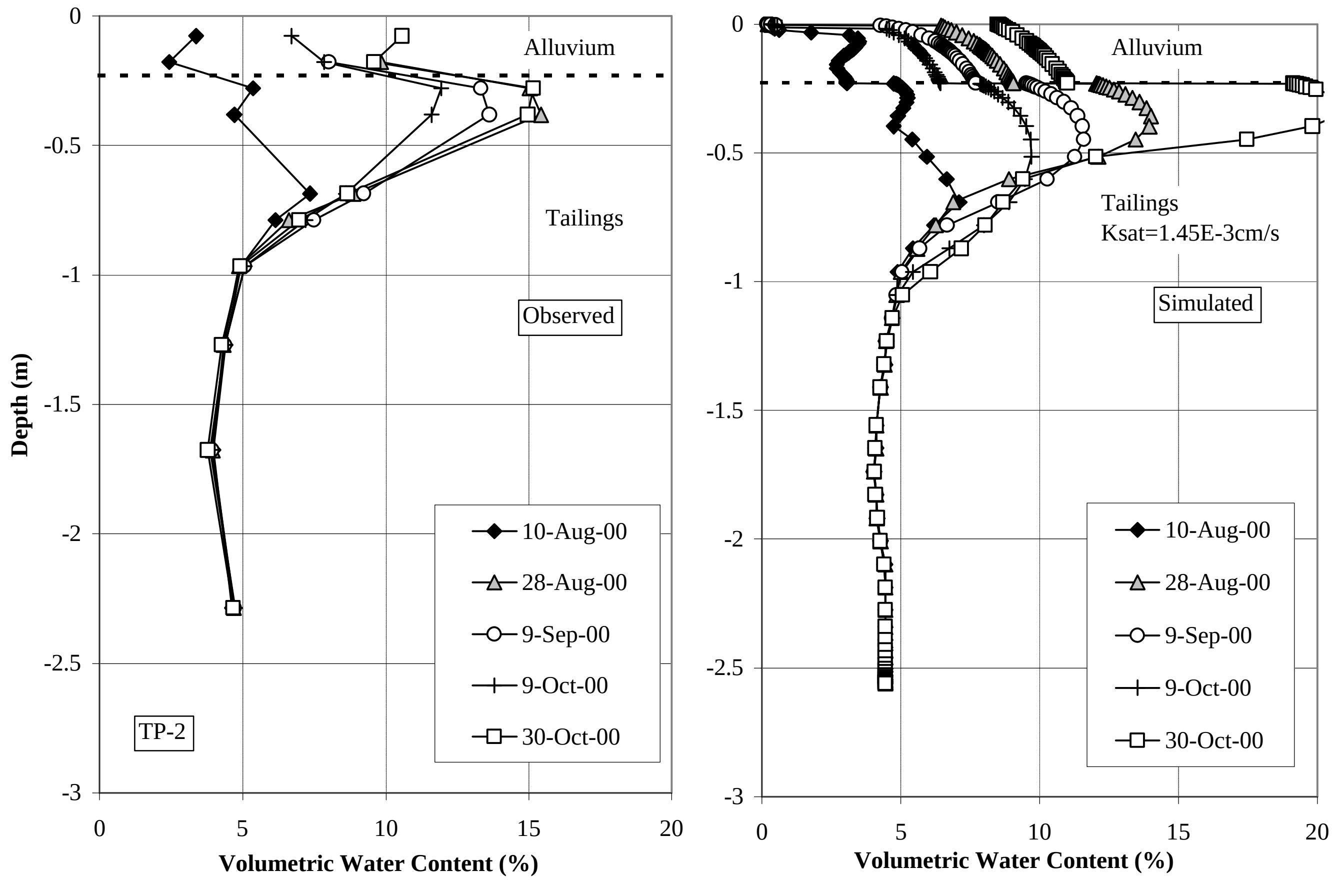

Figure 7. Simulated and observed depth profiles of Volumetric Water Content at TP-2.

curs only on days where the daily maximum temperature is 7°C (44°F) or greater. This assumption is believed to most closely represent actual site conditions (see RGC, 1997). The other vegetation parameters (root zone depth and leaf area index) were determined by sensitivity analyses. A root zone depth of 0.28m (i.e. the depth of the alluvial cover) and a leaf area index of 1 gave the best fit to the observed field data (RGC, 2001b).

Figure 8 shows the simulated and observed depth profiles of volumetric water content for selected dates in test plot TP-1. The hydraulic conductivity of the alluvial cover had to be increased by a factor of 10 relative to the calibrated value for TP-2. The higher Ksat of the existing interim cover at TP-1 is likely due to the presence of vegetation providing root holes and reduced compaction. The hydraulic conductivity of the deeper tailings profile (below 0.46m depth) had to be reduced by an order of magnitude (down to $1.45*10^{-4}$ cm/s) in order to reproduce the very slow observed advance of the wetting front into the deeper tailings profile. This lower (vertical) hydraulic conductivity is consistent with field observations made during test plot construction, which indicated thin layers of finer tailings (silty sand). While of limited vertical extent (a few inches) these layers of finer tailings may be very effective in reducing the vertical hydraulic conductivity of the tailings.

5 CONCLUSIONS

This paper describes the design and installation/instrumentation of cover performance test plots designed to study the performance of a store-and-release ("water storage") cover for final closure of the Questa tailings facility. Initial results for the first year of monitoring suggest that a 0.28m (11") thick alluvial cover with mature vegetation is more effective in reducing net percolation into the deeper tailings profile than either a 0.25m (9") or 0.60m (24") thick alluvial cover without vegetation. The field data support earlier modeling results, which suggested that the tailings are an important component of the store-and-release cover (RGC, 1997). The high porosity of the tailings combined with reduced vertical permeability (due to the presence of thin layers of finer-grained tailings) resulted in storage of the incoming precipitation just below the alluvial cover. Much of this soil moisture was removed from the soil profile during drier periods by evapotranspiration.

Initial calibration of the soil-atmosphere model SoilCover to the test plot data suggested that (i) the existing grass/shrub vegetation (with a 0.28m deep root zone and a LAI=1) in TP-1 significantly improves the removal of moisture from the cover and underlying tailings profile, and (ii) the vertical hy-

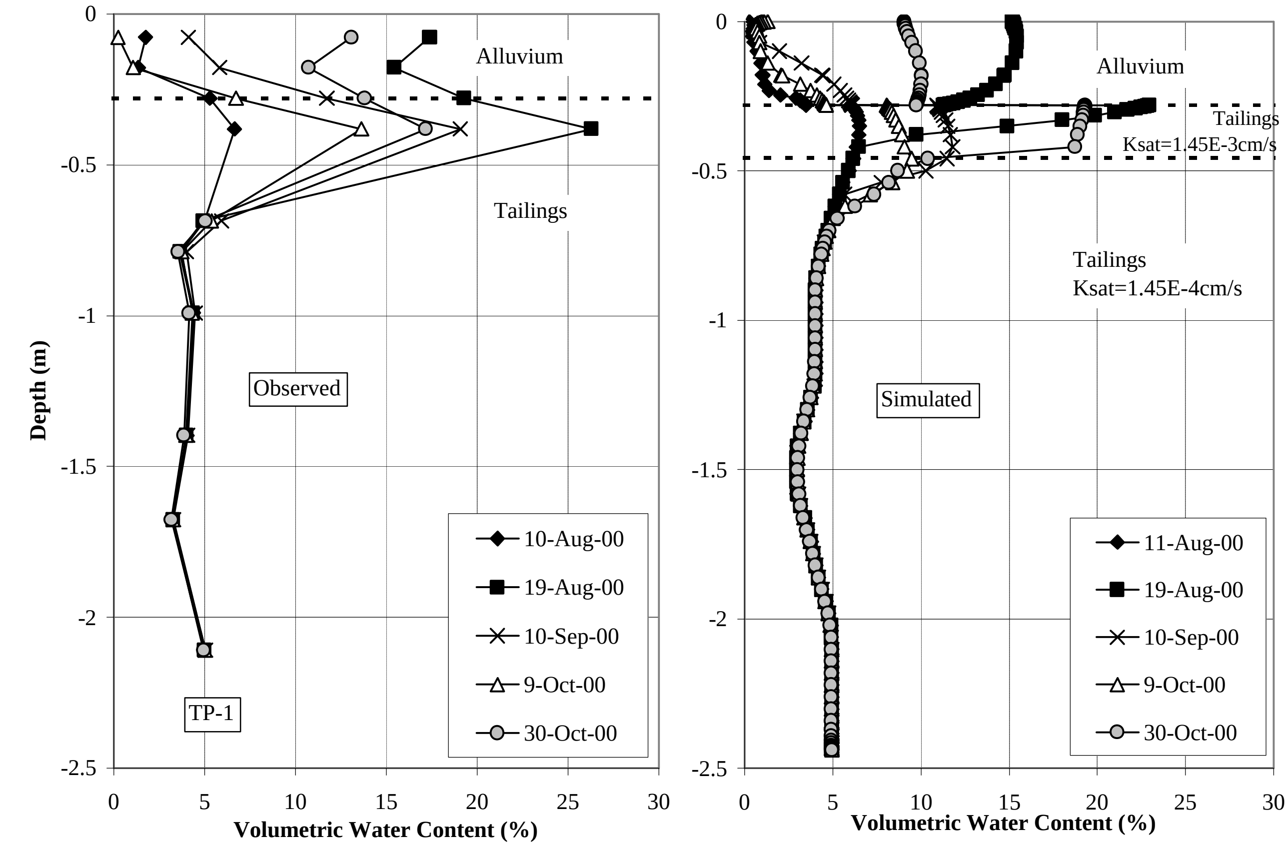

Figure 8. Simulated and observed depth profiles of Volumetric Water Content at TP-1.

draulic conductivity of the *in-situ* tailings is significantly lower than that of the backfilled tailings (and laboratory estimates). These modeling results imply that the observed rates of net infiltration for the barren, backfilled lysimeters may significantly overestimate cover fluxes for long-term (post-closure) conditions. Work is currently in progress to predict long-term cover performance for a range of cover design parameters (e.g. cover thickness) and climate conditions (e.g. wet year vs dry year).

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