

# Cover System Performance in a Semi-Arid Climate on Horizontal and Sloped Waste Rock Surfaces

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## ABSTRACT

BHP Iron Ore initiated a program in January, 1995 at their Mt. Whaleback operation in Newman, Western Australia to develop a decommissioning plan for the waste rock material. The primary research program includes the development of technology for the long term performance of the waste rock dumps with respect to vegetation, slope stability, surface runoff, erosion, and water infiltration. This paper evaluates field performance of cover systems constructed on a horizontal and a sloped waste rock surface. The cover system is constructed using suitable run-of-mine waste material to minimize closure costs. The moisture is subsequently released to the atmosphere as evapotranspiration. Rainfall entering the waste material is buffered due to the presence of the cover material thereby significantly reducing net percolation to the underlying waste rock. The objective is to control acid rock drainage by preventing moisture movement into and through the waste rock material. Two years of field data are presented to illustrate low percolation rates to the underlying waste rock and key performance characteristics of the moisture store and release cover system design. Field data collected to date demonstrates that a moisture store and release cover system constructed with suitable run-of-mine waste material has good potential as a final acid rock drainage control cover system at the Mt. Whaleback site. The performance of the cover system on a sloped surface was significantly altered as compared to placing the cover system on a horizontal surface.

## INTRODUCTION

The Mt. Whaleback iron ore mine is located in the Hamersley Iron Province in the northwestern corner of Australia and situated adjacent to Newman, Western Australia (WA) approximately 1200 km north-northeast of Perth, WA. Development of the mine started in 1968. The mine currently produces approximately 16 million tonnes of iron ore and moves 50 million tonnes of waste material annually. BHP Iron Ore initiated research programs in January 1995 to develop long-term plans for decommissioning of the waste rock material at their Mt. Whaleback operation. More than 2 billion tonnes of waste rock were deposited during the past 30 years. Ultimately, the operation will deposit a total of approximately 4 billion tonnes in waste rock dumps constructed near the open pit.

The oxidized waste rock materials at Mt. Whaleback are geochemically similar and deficient in pyrite as well as carbonates (Graeme Campbell & Associates, 1996). These materials possess little capacity to produce or consume acid. The "un-oxidized" waste rock has varying acid forming potential. The nodular unit of the Mt. McRae Shale contains sulphide-S concentrations ranging from 1.7% to greater than 20% and has a deficiency of carbonates. This unit has the potential to produce up to one tonne of H<sub>2</sub>SO<sub>4</sub> per tonne of waste rock (Graeme Campbell & Associates, 1996). The disseminated unit of the Mt. McRae Shale, as well as additional shale units, have the potential to produce in the range of 50 to 100 kg of H<sub>2</sub>SO<sub>4</sub> per tonne of waste rock (Graeme Campbell & Associates, 1996). The disseminated and nodular Mt. McRae Shale units may

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oxidize rapidly once exposed to the atmosphere. The non-acid forming (NAF) materials typically have low concentrations of pyrite and a low to moderate capacity to consume acid.

The mine site is located in a semi-arid tropical region with a mean annual rainfall of approximately 320 mm. It is common for rainfall to occur over short periods and with high intensity. Annual potential evaporation typically exceeds 3000 mm.

## **BACKGROUND**

Acid rock drainage (ARD) is a major environmental problem facing the mining industry today. ARD is the result of the combined chemical and biological oxidation of sulphide minerals and the release of associated metals, such as iron, aluminium, manganese, and other heavy metals. Mine waste rock and tailings that contain sulphide minerals will react with atmospheric oxygen and water to produce sulphuric acid. Waste rock and tailings materials often have some potential to neutralize the acid generated. The net acid released to the collection system and/or environment is defined as acid rock drainage.

### **Cover System Design Philosophy**

It is common practice to construct single or multi-layered engineered cover systems to control ARD from mine waste rock and tailings. The three principal objectives of cover systems are: 1) to function as an oxygen ingress barrier for the underlying potentially acid forming (PAF) waste material; 2) to function as a water infiltration barrier for the underlying PAF waste material; and 3) to provide a medium for establishing a sustainable vegetation cover that is consistent with the current and final land use of the area. A saturated porous cover material will reduce oxygen ingress in the same manner as a water cover due to the significant reduction in the oxygen diffusion coefficient. The diffusion coefficient will increase as the degree of saturation of the porous material decreases during drainage and evaporative conditions. The degree of saturation that must be maintained within a layer of the cover system to achieve acceptable performance with respect to ARD is site specific and largely dependent on the physical and geochemical nature of the underlying waste.

It is difficult and usually not economically feasible in arid and semi-arid climates to construct a cover system which contains a layer that remains highly saturated thereby reducing oxygen transport. The cover system will be subjected to extended dry periods and therefore the effect of evapotranspiration will be significant. However, subjecting the cover system to evaporative demands can be beneficial in arid climates and result in a reduction of moisture infiltration to the underlying sulphidic waste material. An upper cover surface layer possessing sufficient storage capacity can be used to retain water during a precipitation event or freshet (snowmelt). Subsequent to the increase in moisture storage in the upper layer, it would release a significant portion of pore water to the atmosphere by evapotranspiration during extended dry periods, thereby reducing the net infiltration to the underlying waste. The objective is to control acid rock drainage as a result of buffering rainfall and limiting moisture movement into and through the waste rock material. A cover system with the above objectives is often referred to as a "moisture store and release" system.

### **FIELD TEST PLOT DESIGN AND CONSTRUCTION**

Two 1 ha field test plots were constructed in February, 1997 on a relatively horizontal waste rock surface based on the results of a one-dimensional (1-D) soil-atmosphere modelling exercise. The test plots were constructed with common operational considerations. Test Plot No.1 had a cover thickness of 2 m because this consisted of a single lift of material placed on the original waste rock surface by 240 tonne capacity haul trucks. Two lifts of material were placed during construction of Test Plot No.2 to achieve a 4 m cover layer thickness. A field performance monitoring program was designed and instruments were installed in each test plot in August 1997.

A third test plot (Test Plot No.3) was established on the sloped surface of a historic waste rock dump originally at angle of repose. The sloped surface test plot and associated field performance monitoring system were designed by coupling the results from 1-D modelling with results from a two-dimensional (2-D) saturated-unsaturated model. The slope of the test plot area was reduced to approximately 20° and the surface landscaped to "moonscape" features as part of historic reclamation research activities at the site. The undulating moonscape features were removed and an area approximately 165 m long (top to bottom of slope) x 45 m wide was leveled in January 1998 to serve as Test Plot No.3. An area extending 40 m from the toe of the sloped test plot area was also prepared to collect sediment resulting from surface runoff. A berm was constructed around the sediment collection area to prevent migration of sediment associated with runoff events outside the test plot area. The objective was to qualitatively address the enhanced runoff from the sloped surface test plot.

### **Soil-Atmosphere Modelling**

A soil-atmosphere modelling program was completed using the finite element 1-D model SoilCover (MEND, 1996). SoilCover predicts pressure head and temperature profiles in the soil profile in response to climatic

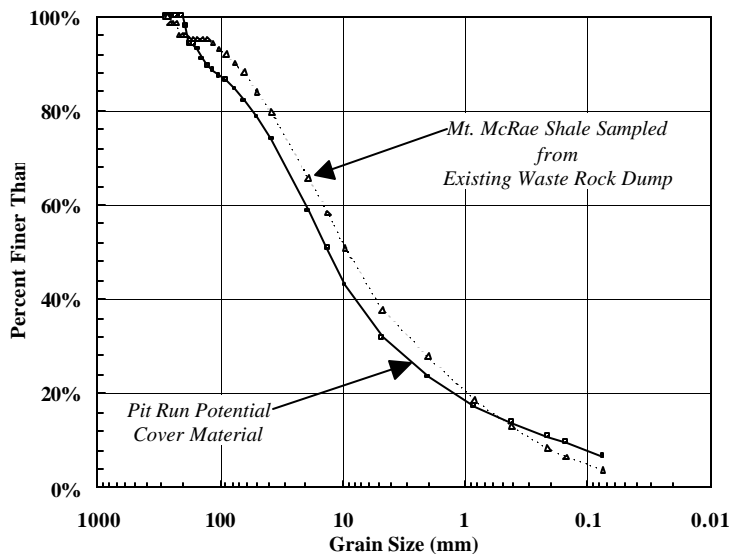
forcing and lower boundary conditions. A key feature of SoilCover is the ability of the model to predict actual evaporation and transpiration based on potential evaporation and predicted soil suction (Wilson *et al.* 1994), as opposed to the user being required to input these surface flux boundary conditions. The actual evapotranspiration rate is generally well below the potential rate during prolonged dry periods because the suction, or negative water pressure, in the soil profile increases as the surface desiccates. SoilCover is also a fully coupled (through the vapour pressure term) heat and mass transfer model which is capable of predicting water vapour movement.

*Climate Input.* The SoilCover model requires input of daily rainfall, net radiation, air temperature, relative humidity, and wind speed. The thirty year historical rainfall data base for Newman was evaluated to determine the maximum rainfall for a 365 day period from October 1 to September 30. The period from October 1 to September 30 was chosen because the lowest monthly rainfall was recorded during the months of September and October during the period of record. This historically dry climate period allowed for the use of a dry initial profile for the model.

The maximum total rainfall for the one year period was approximately 500 mm and occurred from October 1, 1994 to September 30, 1995. Daily air temperature, relative humidity, and wind speed recorded at the Newman meteorological station for the same period was used for the soil-atmosphere modelling. The Newman climate data was supplemented with daily global radiation for the same period as well as sunshine data recorded at Meekathara, WA from 1971 to 1987. The sunshine data was averaged for each day of the year. The average daily data was used to calculate the net radiation for each day of the period modelled using the equations suggested by Maidment (1993). Meekathara is located approximately 400 km south-southwest of Newman and is similar in terms of climate. The potential evaporation as predicted by the Penman (1948) method was approximately 3300 mm.

*Material Properties.* A key design component was the use of run-of-mine waste material placed in small lifts by end dumping with little to no subsequent movement of material by tracked dozers. Therefore, a field sampling program was completed in October 1996 by BHP Iron Ore personnel. Large metal drums ( $\approx$  200 litre volume) were used to collect potential cover materials and waste rock samples for grain size analysis. The potential cover materials were chosen so as to represent run-of-mine oxidized waste. The grain size analysis for 27 bulk samples were completed in December 1996.

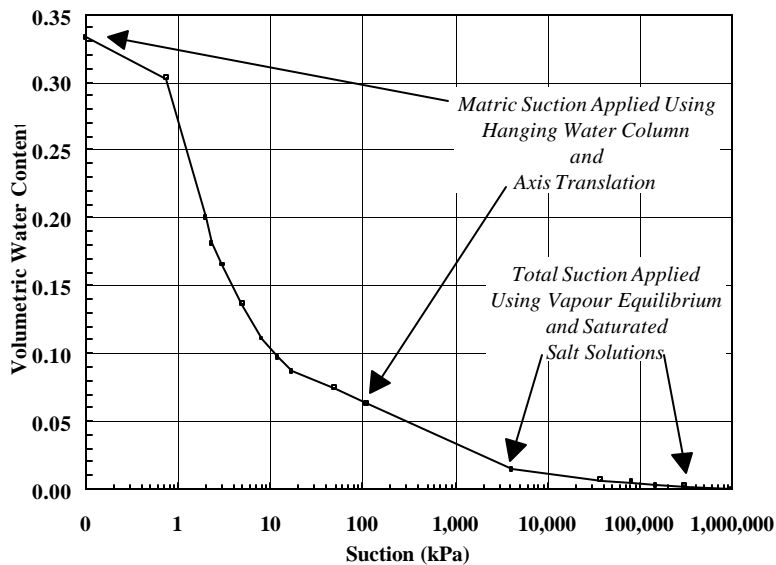
Typical grain size distribution curves for a potential run-of-mine cover material as well as the Mt. McRae Shale waste rock sampled from an existing waste rock dump are shown in Figure 1. The materials are generally coarse in texture and relatively well graded, and while being physically similar are geochemically dissimilar.



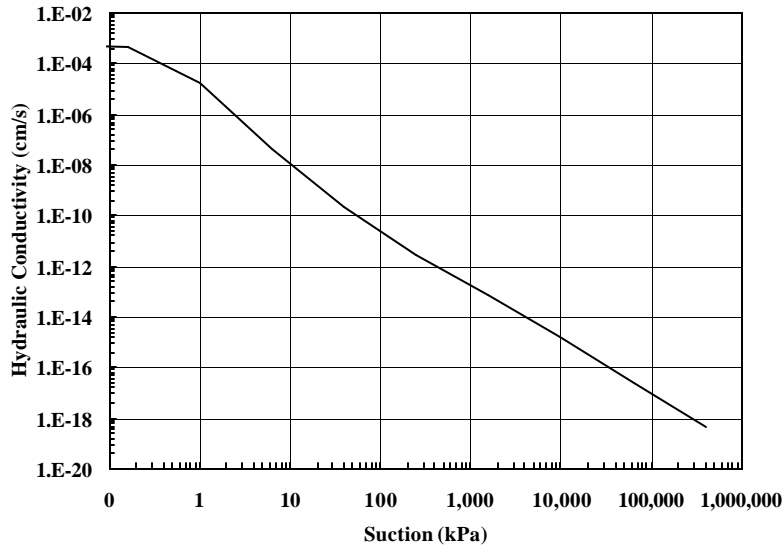
**Figure 1. Typical grain size distributions for the Mt. Whaleback run-of-mine potential cover material and the Mt. McRae Shale waste rock (from Jasper, 1996).**

*Moisture Flow and Storage.* The soil water characteristic curve (SWCC) is a continuous function relating energy and the state of water, and hence describes the water content of a soil as a function of soil suction, or negative pore-water pressure. The SWCC test samples were prepared in the test apparatus to represent insitu moisture and density conditions that were measured prior to and during construction of the horizontal surface test plots. The SWCC test apparatus was constructed from stainless steel (approximately 30 cm in diameter x 60 cm in height) and capable of measuring the SWCC of material passing 75 mm.

The drying portion (i.e. increasing matric suction) of the SWCC is shown in Figure 2. The run-of-mine potential cover material had a distinctive low air entry value with a gradual decrease in the slope of the SWCC near the residual suction, as shown in Figure 2. The saturated hydraulic conductivity was measured using the SWCC apparatus by replacing the lid with a falling head apparatus lid and conducting a falling head test prior to and subsequent to the SWCC test. The hydraulic conductivity function for the run-of-mine potential cover material shown in Figure 3 was based on the methods suggested by Fredlund and Xing (1994) and the measured saturated hydraulic conductivity.



**Figure 2. Drying portion of the soil water characteristic curve for the Mt. Whaleback run-of-mine potential cover material.**



**Figure 3. Hydraulic conductivity function of the Mt. Whaleback run-of-mine potential cover material.**

*Soil-Atmosphere Modelling Results:* The physical model consisted of 2m of cover material over 3m of waste rock and assumed a poorly vegetated cover system, as opposed to good or excellent. A 2m cover thickness was modelled since it was estimated that the thickness of a single lift of material placed by haul trucks on a level surface was approximately 2 meters. The soil-atmosphere numerical modelling predicted the net flux of water entering the waste rock from the base of the 2m cover layer was less than 1% of the 30 year maximum annual rainfall record ( $\approx 500$  mm).

#### **FIELD PERFORMANCE MONITORING**

Field performance of the horizontal surface field test plots (i.e. Test Plot No.1 and No.2) is monitored by a system designed to measure infiltration to the underlying waste rock, changes in moisture conditions within the cover material profile, and climate conditions. Large-scale lysimeters to measure percolation into the underlying waste rock were installed in Test Plots No. 1 and No. 2 in January 1997 prior to construction of the test plots. The remaining components of the monitoring system were installed in August 1997. The performance of the sloped surface field test plot is monitored by a tipping bucket rain gauge as well as moisture and temperature sensors installed laterally from six access culverts. Two sets of access culverts were installed at the top, mid-slope, and base of the slope. The Test Plot No.3 monitoring system was installed during a January 1998 site visit. All field monitoring instruments are controlled by remote data acquisition systems.

#### **SUMMARY OF PERFORMANCE**

Performance of the ARD control cover system trials can be summarized by evaluating: 1) the change in moisture storage within the cover material; and 2) determining the extent of infiltration, following a rainfall event. The response of the field lysimeters is also a good indication of cover performance. The change in moisture storage within the cover material is calculated based on the combined response of the various moisture sensors installed in the profile of the cover material. The extent of infiltration is determined by noting the response to a rainfall event by individual sensors installed at increasing depths below the surface of the cover material.

#### **Change in Moisture Storage**

It was assumed the volume of solids remained relatively constant since construction of the Mt. Whaleback ARD cover system trials. Using a similar assumption for the total volume and a unit area perspective, the

total volume is equal to the depth of the run-of-mine material placed on the test plot in question. Accordingly, the volume of voids also remained constant since construction.

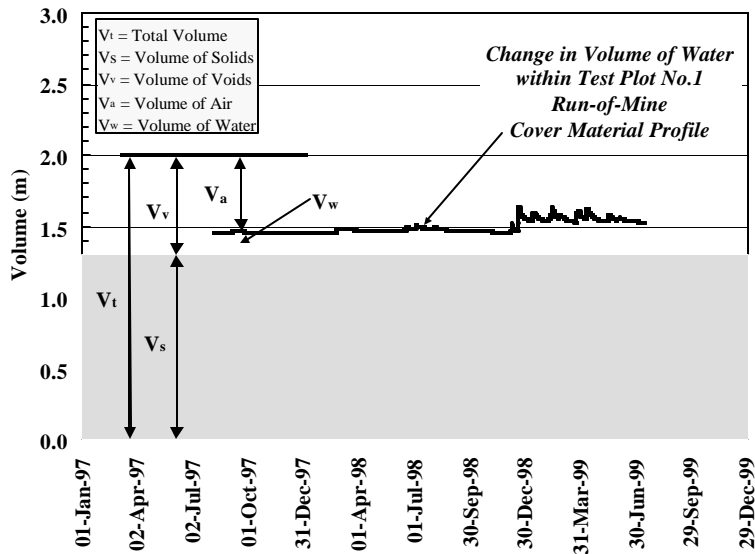
*Test Plot No.1:* A porosity equal to 0.34 was used for the run-of-mine cover material during moisture storage calculations and was based on field and laboratory measurements. Run-of-mine cover material thickness at Test Plot No.1 is approximately 2 m. Therefore, the volume of voids,  $V_v$ , or the maximum volume of water storage available for infiltrating water is equal to the porosity multiplied by the depth, or approximately 0.68 m. This is also representative of the “assumed cover thickness” for the sloped test plot (Test Plot No. 3). The maximum volume of water storage available for Test Plot No. 2 is approximately 1.36 m (i.e.  $0.34 \times 4$  m).

The ratio between the volume of air,  $V_a$ , and volume of water,  $V_w$ , within the test plot run-of-mine cover material profiles is based on the response of the moisture content sensors prior to, during, and subsequent to rainfall events. The sensors measure an increase in the volume of water within the run-of-mine cover material profiles as the water content increases in response to rainfall. A subsequent decrease in the volume of water within the run-of-mine cover material profiles can be calculated as the water content decreases in response to evaporation.

Figure 4 shows the change in the volume of water within the Test Plot No.1 run-of-mine cover material profile since construction. Approximately 1043 mm of rain was recorded at the horizontal surface test plot area during this period. A net increase of approximately 70 mm in the volume of water within the Test Plot No.1 run-of-mine cover material profile was measured for the same period. Rainfall recorded during the months of December 1998 to March 1999 inclusive was 562 mm and led to a 118 mm net increase in moisture storage within the cover material profile. The rainfall recorded during this period was approximately 240 mm greater than the average annual rainfall for the site and more than 60 mm greater than the wet year climate record used during the cover system design modelling. Approximately 161 mm of unseasonable rainfall was recorded during the next three months to the end of June 1999. The total rainfall recorded for the site during the wet season was 723 mm during the period of December 1998 to June 1999. The total was 225% greater than the average annual rainfall and 145% greater than the maximum annual rainfall recorded over a 30 year period. Surface evaporation led to a net decrease in moisture storage within the cover profile during the three month period of April 1999 to June 1999 from approximately 118 mm to 70 mm even though significant unseasonable rainfall occurred. It is anticipated that forthcoming extended dry climate conditions will result in further evaporation from the Test Plot No.1 run-of-mine cover material profile and a return to antecedent moisture conditions. In other words, at the current time the Test Plot No.1 run-of mine cover material profile has not had the opportunity to respond to atmospheric demand for moisture, decrease in moisture content following rainfall during the months of December 1998 to June 1999 inclusive, and return to moisture conditions prior to December 1998.

Rationale for the anticipated return to antecedent moisture conditions was based on the response of the Test Plot No.1 run-of-mine cover material profile to the significant single rainfall event in February 1998 ( $\approx 80$  mm). Rainfall during the February 1998 event caused an approximate 40 mm net increase in the volume of water within the Test Plot No.1 run-of-mine cover material profile. The net increase was eventually reduced to a negligible volume following moderate unseasonable June 1998 rainfall and subsequent seasonable dry climate conditions, as shown in Figure 4. The high potential evaporative climate conditions following wet climate conditions is a key factor controlling hydraulic performance of the Mt. Whaleback ARD control cover system trials. Evaporation from the cover material profile during the dry climate conditions allowed the profile to return to antecedent conditions and begin the “wet season” at a low degree of saturation in preparation for infiltration resulting from rain.

The 70 mm net increase in the volume of water within the Test Plot No.1 run-of-mine cover material profile since construction represents approximately 10% of the volume of voids available in the profile (i.e.  $70 \text{ mm} \div 680 \text{ mm}$ ). The antecedent volume of water in the cover material profile is approximately 20% of the volume of voids available (i.e.  $137 \text{ mm} \div 680 \text{ mm}$ ). Hence, approximately 30% of the volume of voids available for water within the Test Plot No.1 cover material profile were filled with water (i.e.  $[70 \text{ mm} + 137 \text{ mm}] \div 680 \text{ mm}$ ) following rainfall during the months of December 1998 to June 1999 inclusive. It is fundamental to understand that an additional 70%, or 475 mm, of the volume of voids are currently filled with air and theoretically available for infiltration of water.



**Figure 4. Cumulative change in moisture storage (i.e.  $V_w$ ) in Test Plot No.1 run-of-mine cover material profile .**

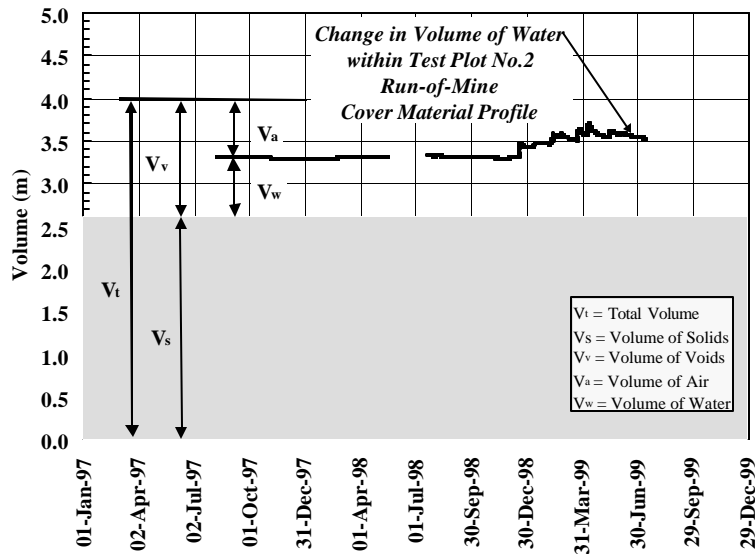
*Test Plot No.2:* Figure 5 shows the change in the volume of water within the Test Plot No.2 run-of-mine cover material profile since construction. A 227 mm, or 16.7%, net increase in the volume of water within the Test Plot No.2 run-of-mine cover material profile was measured since construction.

The volume of water within the Test Plot No.2 run-of-mine cover material profile subsequent to construction was approximately 665 mm, or 49% of the volume of voids. Rainfall during placement of the Test Plot No.2 run-of-mine cover material appears to have led to higher “antecedent” moisture conditions within the Test Plot No.2 cover material as compared to Test Plot No.1. The 227 mm net increase in the volume of water within the Test Plot No.2 run-of-mine cover material profile was a result of rainfall during the months of December 1998 to June 1999 inclusive. The current volume of water within the Test Plot No.2 profile represents approximately 66% of the volume of voids (i.e. [227 mm + 665 mm] ÷ 1360 mm) available for air and/or water. Hence, approximately 34%, or nearly 470 mm, of the volume of voids is currently filled with air and theoretically available for further storage of water infiltration resulting from rain.

The Test Plot No.2 run-of-mine cover material profile responded to the February 1998 rainfall event in a similar manner to that described for Test Plot No.1. That is, moisture conditions prior to the February 1998 rainfall event were achieved following an opportunity for the cover material profile to respond to atmospheric demand for moisture. Therefore, it is reasonable to anticipate the increase in the volume of water within the Test Plot No.2 run-of-mine cover material profile will dissipate during the forthcoming dry climate conditions. It should be noted that vegetation of the test plots was not introduced (other than a small amount of volunteer vegetation) during the monitoring period. Hence, the true potential of the moisture store and release cover system for the Mt. Whaleback site will be realized following implementation of the vegetation cover.

### Depth of Infiltration

Suction is a fundamental measure of moisture conditions in an unsaturated porous medium. It is a measure of the negative pressure head present in the material and a suction sensor can be thought of as a piezometer of the unsaturated zone. In simple terms, low suctions imply a high degree of saturation and high suctions imply a low degree of saturation. The response of the suction sensors installed at the test plot run-of-mine cover material profiles can be used to estimate the depth of infiltration, or increase in moisture conditions with depth, as a result of rainfall. A decrease in suction recorded by a particular sensor implies an increase in water content (i.e. degree of saturation) and is an indication of the depth of advancement of a wetting front resulting from rainfall.



**Figure 5. Cumulative change in moisture storage (i.e.  $V_w$ ) in Test Plot No.2 run-of-mine cover material profile.**

*Test Plot No.1.* The response of the suction sensor installed at 2 m below the surface of the Test Plot No.1 run-of-mine cover material profile (i.e. at the base of the run-of-mine cover material placed during construction) is shown in Figure 6 for the measurement period covering August 1997 to June 1999. Rainfall during the 1997-1998 wet season infiltrated to a depth of 2 m in the Test Plot No.1 run-of-mine cover material because suction decreased by one order of magnitude from approximately 2,000 kPa to approximately 200 kPa.

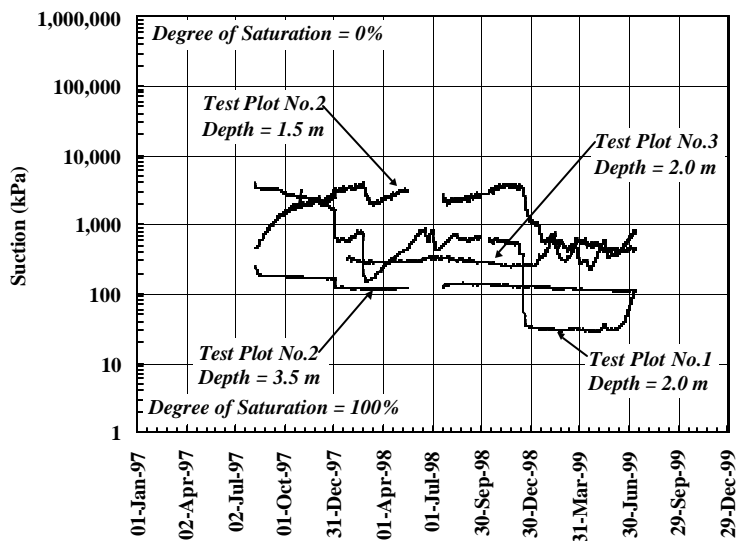
Suction measured at a depth of 2 m increased to approximately 1,000 kPa following the 1997-1998 wet season as a result of evaporation. This was followed by a marginal decrease in suction, as moisture infiltrated to the base of the run-of-mine cover material profile in response to June, 1998 rainfall. Rainfall during the months of December, 1998 to mid-June, 1999 led to a decrease in suction from approximately 800 kPa to approximately 30 kPa at a depth of 2 m in response to infiltration, as shown in Figure 6. Suction subsequently increased to 100 kPa during the latter part of June 1999.

*Test Plot No.2.* The suction sensor installed at a depth of 2 m below the surface of the Test Plot No.2 run-of-mine cover material profile did not function properly throughout the monitoring period shown in Figure 6. However, the response of the suction sensors installed at depths of 1.5 m and 3.5 m bound the depth of water infiltration following rainfall during the monitoring period. The suction sensor installed at 1.5 m responded to an advancing wetting front following rainfall while the suction sensor installed at 3.5 m measured a relatively constant suction. Response by the latter sensor indicates no change in moisture conditions at a depth of 3.5 m in the Test Plot No.2 run-of-mine cover material profile throughout the monitoring period.

*Test Plot No.3.* The response shown on Figure 6 of the Test Plot No.3 suction sensor installed at a depth of 2 m illustrates the impact of a sloped waste rock surface on infiltration resulting from rainfall at the Mt. Whaleback site. Measured suction at a depth of 2 m below a sloped run-of-mine cover material surface did not decrease during the monitoring period. This is in sharp contrast to the response of the suction sensor at 2 m below the horizontal surface of the Test Plot No.1 run-of-mine cover material surface where suction responded dramatically to infiltration following rainfall. It appears that the sloped surface at Test Plot No.3 enhanced surface runoff during rainfall and decreased infiltration as well as the depth of infiltration.

### Percolation from the Base of the Run-of-Mine Cover Material

O'Kane *et al.* (1998) presented the design of the two lysimeters installed into the existing waste rock dump surface at each of the Test Plot No.1 and Test Plot No.2 ARD control cover system trials prior to placement of run-of-mine cover material. No water reported to the base of the lysimeters installed to monitor percolation from the base of the Test Plot No.1 and Test Plot No.2 run-of-mine cover material profiles during the period monitored until early June 1999. Water was measured to a depth of 3.8 cm in early June 1999 and increased by 1.9 cm to 5.7 cm (the original 3.8 cm was not removed) in one of the Test Plot No.1 lysimeters in late June 1999. The free water surface at the base of the lysimeter is likely in response to the extreme rainfall conditions during the preceding wet season. A rationale for the difference in performance between the two Test Plot No.1 lysimeters has not yet been developed. It is anticipated the difference is a function of the lysimeter backfill properties (i.e. the waste rock particle size distributions, placement densities, and moisture conditions). A field response modelling program currently in progress (i.e. calibration of the soil-atmosphere numerical) should provide the required insight.



**Figure 6. Depth of infiltration measured by soil suction sensor response in Test Plot No.1 (2.0 m), Test Plot No.2 (1.5 m and 3.5 m), and Test Plot No.3 (2.0 m).**

### SUMMARY AND CONCLUSIONS

Evidence that infiltration advanced to a depth of approximately 2 m below the horizontal surface of the Test Plot No.1 (2 m of cover material) and Test Plot No.2 (4 m of cover material) run-of-mine cover material was obtained during the August 1997 to June 1999 monitoring period. The infiltration did not advance to a depth of 2 m during the monitoring period at the sloped surface field test plot. It would appear enhanced surface runoff at the sloped surface test plot led to the change in cover performance and significantly reduced infiltration.

Infiltration resulting from rainfall during a February 1998 event led to an increase in the volume of water within the run-of-mine cover material profiles. However, the increase in the volume of water did not reach the capacity of the cover material profiles. Moisture conditions within the profiles returned to antecedent conditions during the subsequent dry climate conditions.

Rainfall during the months of December 1998 to June 1999 was nearly 2.3 times greater than the average annual rainfall and more than 1.4 times greater than the maximum annual rainfall recorded at the site. The extreme rainfall conditions led to a 70 mm net increase in the volume of water within the Test Plot No.1 run-of-mine cover material profile during the period monitored. A free water surface was measured at the base of one of the two Test Plot No.1 lysimeters. The Test Plot No.1 cover material profile showed a consistent drying trend due to surface evaporation since the extreme rainfall conditions.

A 16.7% increase in the volume of water stored within the Test Plot No.2 run-of-mine cover material profile was measured during the period since construction of the test plots (August 1997 to June 1999 inclusive). No water reported to the two lysimeters installed to measure net percolation from the base of the 4 m of cover material to the underlying waste. The performance of the lysimeters was verified by the response of the suction sensors at depths of 1.5 m and 3.5 m. The suction sensor installed at 1.5 m responded to an advancing wetting front (i.e. decreased in suction) while the suction sensor installed at a depth of 3.5 m did not record a change in suction throughout the period monitored. A consistent drying trend was also evident in the Test Plot No.2 run-of-mine cover material profile following the recent wet season.

The data presented for a twenty-one month monitoring period demonstrated the potential for success of the "moisture store and release" type cover system at the BHP Iron Ore Mt. Whaleback site. It is fundamental to understand though that the twenty-one months of monitoring are simply a brief "snapshot" in time and should not be taken as being indicative of long term performance. The improved understanding in performance of the moisture store and release ARD control cover system trials is the direct benefit of the current field performance monitoring program. Key factors controlling performance will continue to be developed and understood. The data base required for field calibration of a coupled heat and mass transfer soil-atmosphere saturated-unsaturated numerical model is being developed. Accurate, and more importantly defensible, predictions for long term performance of the Mt. Whaleback ARD control waste rock cover system can only be obtained using a predictive tool properly calibrated to field conditions.

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