Klohn Crippen Berger

June 11, 2014

Northern Minerals Limited
Level 1, 675 Murray Street
West Perth, Western Australia
6005

Lisa Chandler
Senior Environmental Advisor

Dear Dr. Chandler:

Browns Range Project
Supplementary technical input for API update – TSF Cover Assessment

1 INTRODUCTION

Klohn Crippen Berger Ltd (KCB) was commissioned by Northern Minerals Limited (NTU) to undertake technical studies for the Browns Range Project. These studies are to support submission of an update to the Assessment on Proponent Information (API) to the Office of the Environmental Protection Authority (OEPA).

This letter report provides a review of the tailings storage facility (TSF) cover design, concepts and performance measures. As part of the investigation, Vadose/W modelling was used to determine the flux of water through the cover materials to characterise the behaviour of each proposed cover configuration.

2 SCOPE OF SERVICE

KCB have conducted a preliminary TSF cover system assessment based on the following general guidelines:

- assess “store and release” cover system options, based on an agreed rainfall criteria; and,
- assess the performance of a cover when a “capillary break” layer is included in the cover system design.

KCB have undertaken the cover assessment based on the following:

1. Three conceptual TSF cover profiles were developed based on the general guidelines provided above. These profiles were discussed with NTU personnel prior to commencement of the analytical assessment. As part of these discussions, the hydraulic parameters of the layers for each cover system were agreed upon and were adopted for subsequent analytical assessment.

Klohn Crippen Berger Ltd. • Level 4 - 673 Murray St • West Perth WA 6005 • Australia
+61.8.9486.5400 t • +61.8.9486.5499 f • www.klohn.com

2. Analytical assessment of each of the cover profiles was conducted using Vadose/W 1D (two-dimensional unsaturated zone modelling platform) to assess the infiltration flux and water retention capabilities of the selected cover systems. Assessment of oxygen ingress through the cover systems was not undertaken as part of this assessment.
3. Sensitivity analyses were conducted to evaluate the effect of different cover layer inputs (i.e. hydraulic parameters, layer configurations).

2.1 Cover Materials

2.1.1 General

There is information currently available on the properties of the tailings and potential cover materials (locally sourced). Four documents have been produced that relate to the properties of the cover materials, and were derived from work previously undertaken at the Project site. These comprise:

- Golder (2014) Preliminary Geotechnical Investigation Report – Stage 1: Browns Range Project.
- Golder (2013) Tailings Geotechnical and Rheological Laboratory Testing.
- Outback Ecology (MWH Australia) (2014a) Analogue Slopes: Soil and Vegetation Assessment.
- Outback Ecology (MWH Australia) (2014b) Baseline Soils and Landform Assessment.

Based on the information provided in the aforementioned reports, there are four materials that will be incorporated into the cover design for this assessment:

- Topsoil/growth medium – this material has been characterised as a standard sandy loam (MWH, 2014a) and represent the sandy plains across the Project site.
- Tailings – the client has advised that the tailings have a K_{sat} of ~ 1.00E-07 to 1.00E-08. Based on this information the compacted tailings material was believed to have a K_{sat} of ~1.00E-09 (Golder, 2014).
- Storage layer material – this material represents the sandy clay loam from the sand over gravel plains (~30 – 160 cm depth) and generally drains rapidly.
- Capillary break – this material represents the sandy loam from the colluvium gravelly soils and contains a portion of coarse fragments.

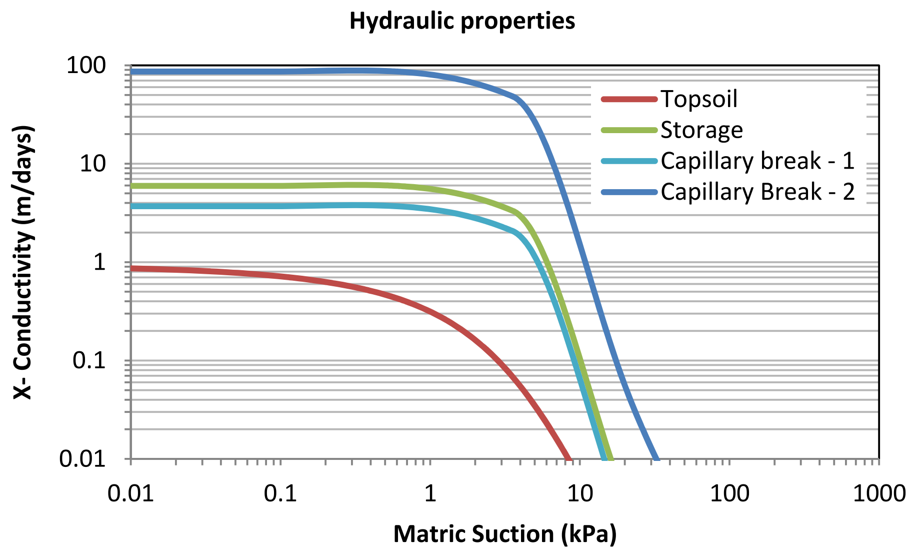
Clay was considered as a potential cover material; however, there is a shortage of the material on site and was therefore removed as a viable cover layer option. As a substitute for clay, one of the scenarios (Scenario 2) considers compacted or amended tailings as a low permeability layer.

Based on the previous investigations, the assumed material properties for each of the cover materials are presented in Table 2-1. The hydraulic conductivity function and volumetric water content curves for each of these materials are shown in Figure 2-1 and Figure 2-2, respectively.

Table 2-1 Material Characteristic Summary

Material	Texture	Coarse fragments (%)	K_{sat} (m/s)	K_{sat} (m/day)	Drainage class	Total volumetric water content (%)
Topsoil	Sandy Loam	4	1.03E-05	8.88E-01	Moderate	42
Storage Layer	Sandy Clay Loam	35	6.89E-05	5.95E+00	Rapid	45
Capillary Break	Sandy Loam	68	4.28E-05	3.70E+00	Moderate - rapid	50
Tailings (1)	Clay / Clayey silt	-	1.00E-08	8.64E-04	-	-
Tailings (2)	Clay / Clayey silt	-	1.00E-07	8.64E-03	-	-
Compacted tailings	Clay / Clayey silt	-	1.00E-09	8.64E-05	-	-

*There are no water holding capacity measurements available for the tailings material; therefore, a nominal value of 45% was applied which is consistent with the clay/tailings material.



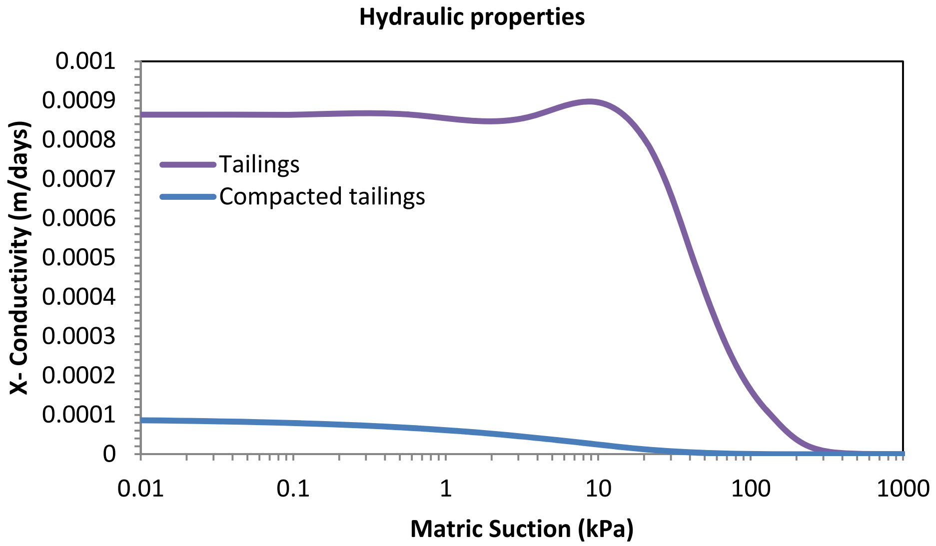


Figure 2-1 Hydraulic conductivity functions for each of the selected cover materials

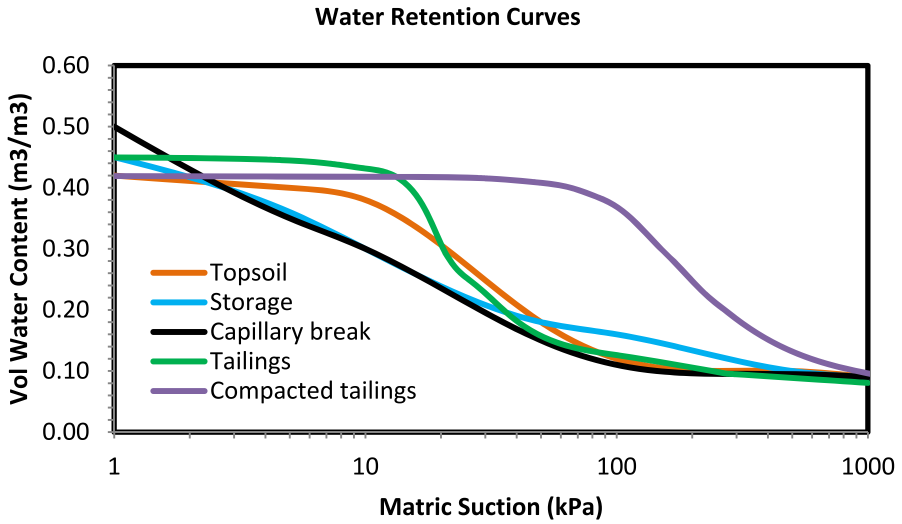


Figure 2-2 Water retention curves for each of the selected cover materials

2.2 Climate and Vegetation

2.2.1 Meteorological Inputs

Climatic data was compiled from the Australian Governments Bureau of Meteorology (BOM, 2013) for the Halls Creek airport climate Station (ID 002012) (approximately 150 km northwest).

Daily data from 2004 and 2012 was used for temperature, relative humidity (RH), precipitation, wind speed and solar radiation (Appendix I). These years were used as they represent the average over the entire dataset. The most extreme rainfall event, over the monitoring history (70 years), was measured to be 202.2 mm within a 24 – hour period (January, 1959); therefore, this value was incorporated into some of the model rainfall scenarios to represent an extreme event.

2.2.2 Vegetation

Vadose/W allows the modelling of evapo-transpiration if a vegetated surface is applied. Estimates for desert plant species and growing stages was used as input to the model for factors such as the leaf area index, permanent wilting point and root depth. Detailed functions used in the analyses are provided in Appendix II. There was no data available on endemic plant species in the area proposed planted on the TSF cover.

2.3 Final Cover Configurations

The final dump configuration has been developed based on the philosophy that the final cover should act to minimise rainfall infiltration into the underlying tailings and mitigate capillary rise of salts from the tailings to the surface. One dimensional modelling was undertaken to evaluate water infiltration through the cover to the tailings. The impermeable layer at the base of the tailings has been included in the models because the TSF will be lined with a low permeability liner; therefore, it is assumed that there will be no significant losses through the base of the TSF. The associated 1-D configuration for the cover scenarios is presented in Figure 2-3. The three final cover configurations and justification of their selection is summarised in Table 2-2.

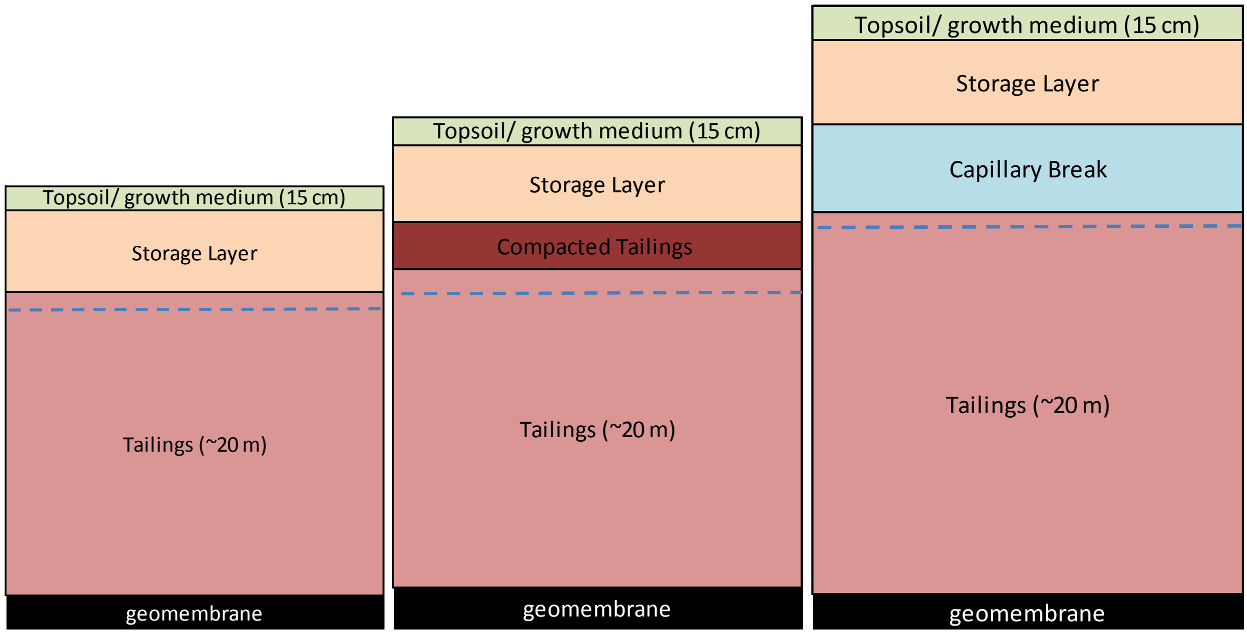


Figure 2-3 Cover Types (configurations). From left: Type 1, Type 2 and Type 3.

Table 2-2 Cover types and justification for material types and configuration

Cover type	Cover Materials	Justification / Functionality
Base Case	None	Provides an indication of flux associated with uncovered/exposed tailings.
Type 1	Topsoil; storage layer	Simplified cover to store rainfall in the wet season and allow evaporation in the dry season. The storage material should be thick enough to store a 202 mm, in 24 hours, extreme rainfall event and coarse enough to mitigate capillary rise from the tailings.
Type 2	Topsoil; storage layer; compacted or amended tailings	Cover to store rainfall in the wet season and allow evaporation in the dry season. The storage material should be thick enough to store a 202 mm, in 24 hours, extreme rainfall event and coarse enough to mitigate capillary rise from the tailings. The tailings on the surface is to be compacted (via traffic) or otherwise amended to lower the hydraulic conductivity and reduce infiltration.
Type 3	Topsoil; storage layer; capillary break	Cover to store rainfall in the wet season and allow evaporation in the dry season. The storage material should be thick enough to store a 202 mm, in 24 hours, extreme rainfall event and coarse enough to prevent capillary rise from the tailings. Inclusion of a coarse layer to act as a capillary break between the tailings and storage layer.

2.4 Model Approach

The Vadose/W (2012) modelling platform was used to conduct the vadose zone and soil cover modelling. The objective of the modelling is to assess the difference in flux reaching the tailings for different cover types (Type 1, Type 2 and Type 3). The material types, material properties and thickness of some of the layers were varied for sensitivity analysis. For some of the scenarios the storage layer was decreased in thickness from 1 m to 0.5 m and 10 cm. Also, a compacted (or amended) tailings layer and capillary break were included in some of the models. For the Type 1 configuration, the vegetation was also removed from the cover surface to assess the effects of vegetative cover.

Fourteen model scenarios were simulated to evaluate the following configurations (top down):

- Scenario 1a – Base case (no cover).
- Scenario 2a – Type 1: vegetation; topsoil (15 cm); storage layer (1 m).
- Scenario 3a – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m).
- Scenario 4a – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm).
- Scenario 5a – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer.
- Scenario 6a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m)
- Scenario 7a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m)

In addition to the sensitivity scenarios and different cover configurations, an extreme rainfall event was applied to each of the cover types. This rainfall event is based on the highest total rainfall experienced within a 24 – hour period over the 70 years of data collection (i.e. 202.2 mm; January, 1959). The additional models including the extreme event include (top down):

- Scenario 8a – Base case (no cover). Extreme event applied.
- Scenario 9a – Type 1: vegetation; topsoil (15 cm); storage layer (1 m). Extreme event applied.
- Scenario 10a – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m). Extreme event applied.
- Scenario 11a – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm). Extreme event applied.
- Scenario 12a – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m). Extreme event applied.
- Scenario 13a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m). Extreme event applied.
- Scenario 14a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m). Extreme event applied.

Additional simulations were conducted based on a tailings saturated hydraulic conductivity of 1.00E-07 m/s (Golder, 2014). This was undertaken to assess the sensitivity of the simulated flux as a result of tailings hydraulic conductivity. Similarly, model scenario 14b was re-simulated with a capillary break hydraulic conductivity of 1.00E-03 m/s (i.e. scenario 15).

All other model assumptions were the same for each scenario, including:

- Model duration: start July, 2025, and allowed to run for 6 years (results for years 4 -6 reported);
- Initial water table (~1 m below the top of the tailings); and,
- Climate and vegetation characteristics (Appendix II).

The initial water pressures are obtained from the starting water level (i.e. ~1 m below top of tailings), and the pore-water pressures vary hydrostatically below and above this level. Surface water is allowed to pond on boundaries; water is stored on the surface (nodes) and allowed to evaporate or infiltrate during later time steps.

3 RESULTS

3.1 Infiltration and evaporation at surface

Results of the modelling indicate that surface infiltration (Figure 3-1 and Figure 3-2) and surface evaporation (Figure 3-3 and Figure 3-4) are the same for each of the models with the same climate and vegetation data. However, there is a slight difference in infiltration and evaporation between models using average rainfall data and the extreme rainfall event.

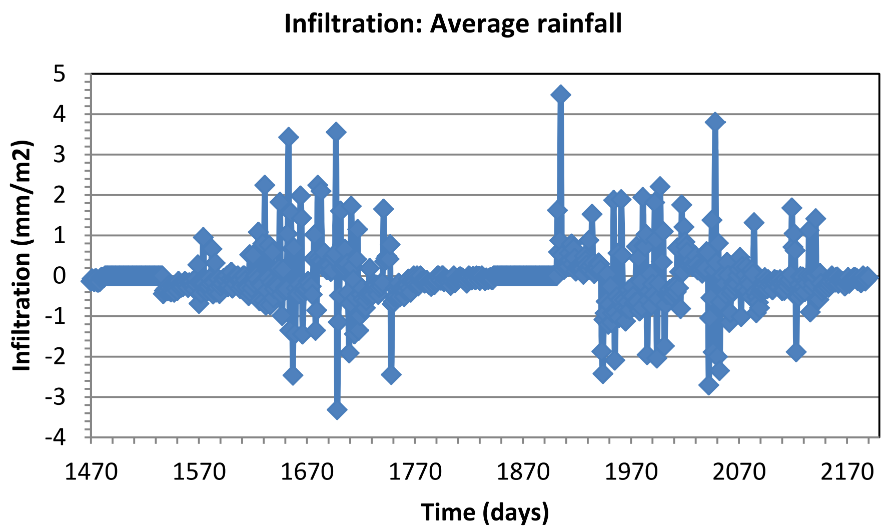


Figure 3-1 Infiltration: **Average rainfall, years 4 – 6 (Note: positive values represent infiltration of water into the cover)**

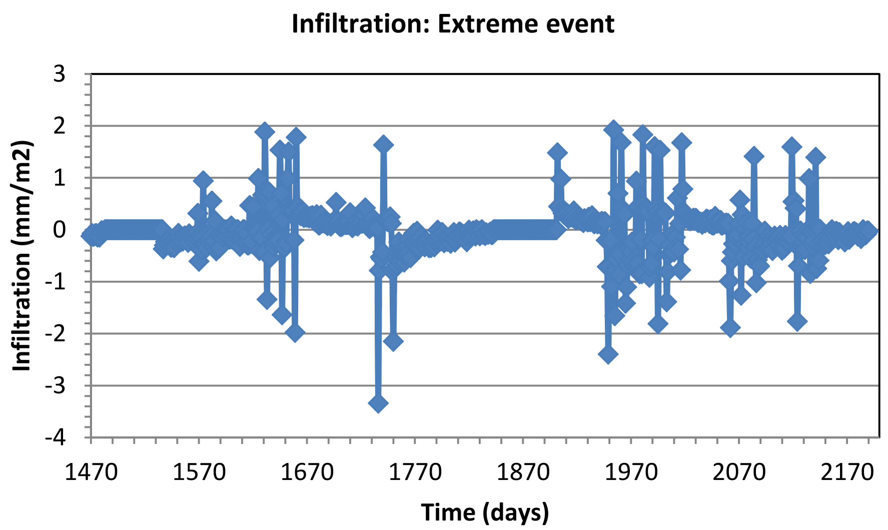


Figure 3-2 Infiltration: **Extreme rainfall, years 4 – 6 (Note: positive values represent infiltration of water into the cover)**

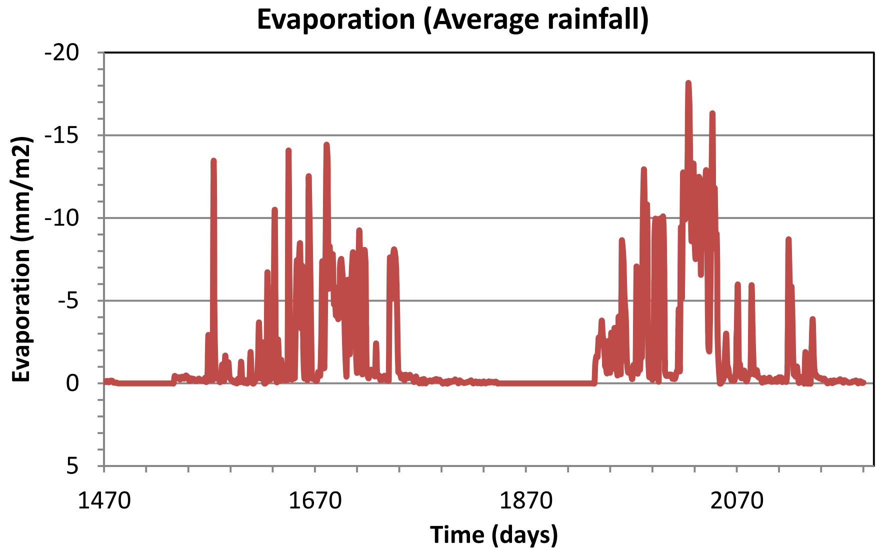


Figure 3-3 Evaporation: **Year 4 to 6, extreme rainfall event (Note: negative values represent removal of water via evaporation)**

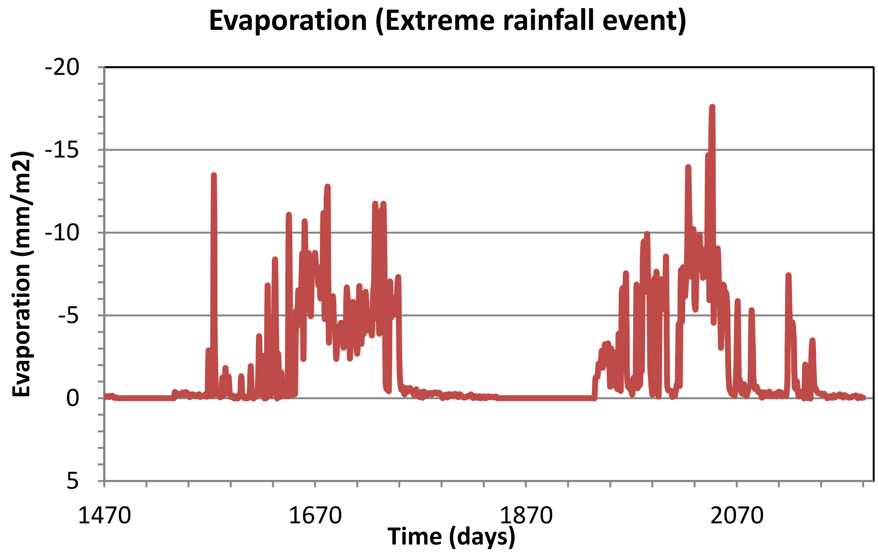


Figure 3-4 Evaporation: **Year 4 to 6, extreme rainfall event (Note: negative values represent removal of water via evaporation)**

3.2 Water Balance

A summary of the water balance is shown for an example (Scenario 2a) in Figure 3-5. The graphs are generated at every time step. The water balance indicates:

- Approximately 1.38 m^3 of rain accumulated during the simulation (years 4 – 6);
- Approximately 1.44 m^3 of water was removed from the domain due to evaporation;
- Approximately 0.001 m^3 of water was removed from the domain due to plant transpiration; and,

- A storage change of approximately 0.06 m^3 of water occurred within the domain (loss due to evaporation).

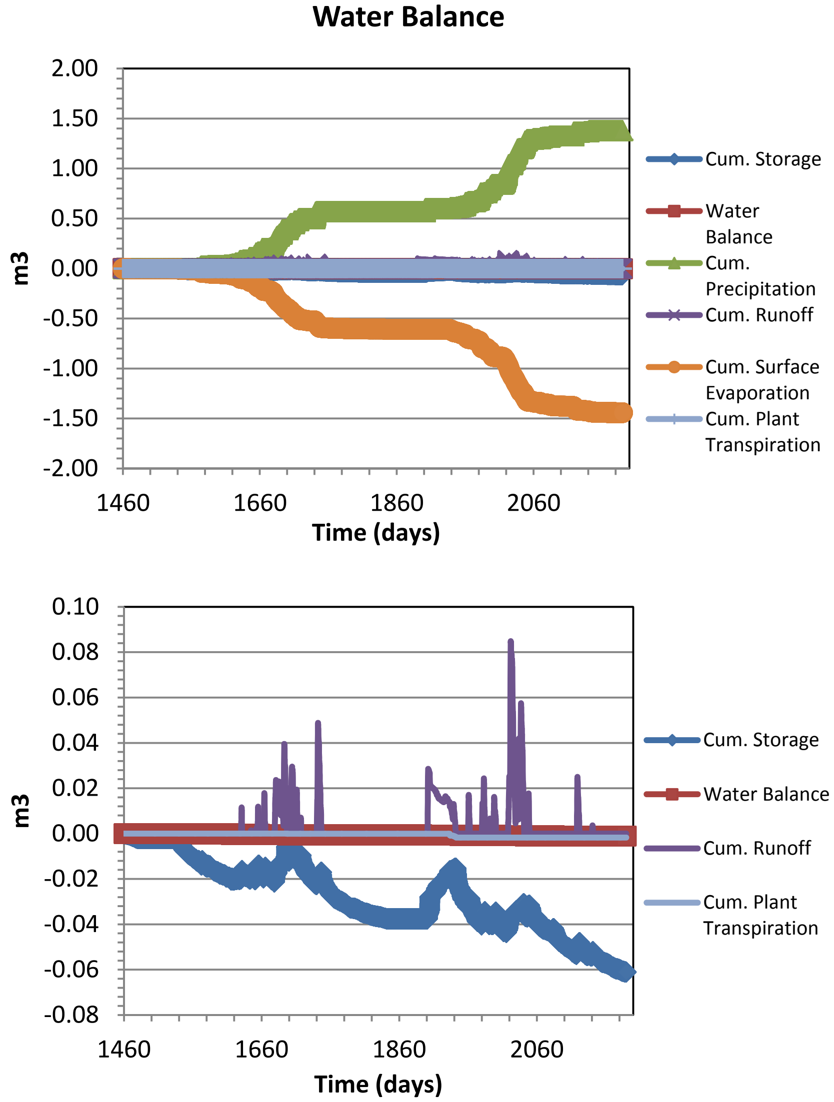
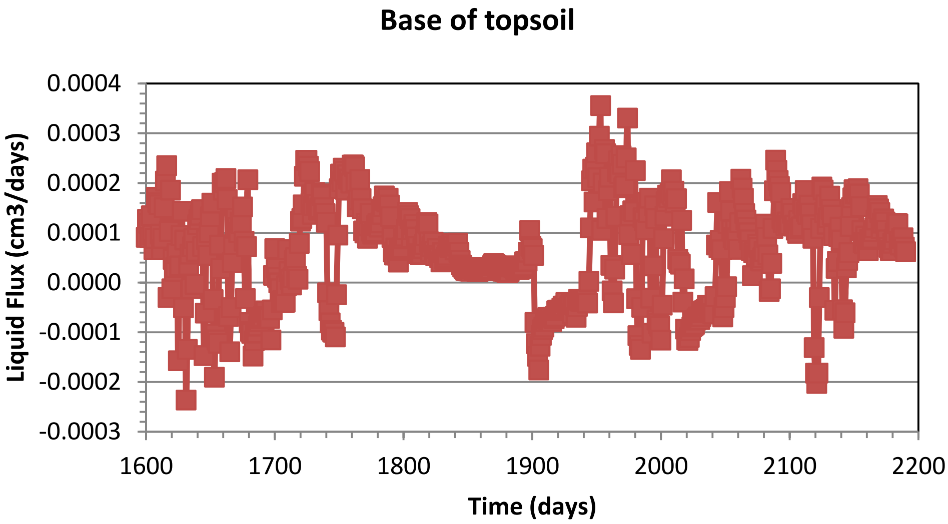
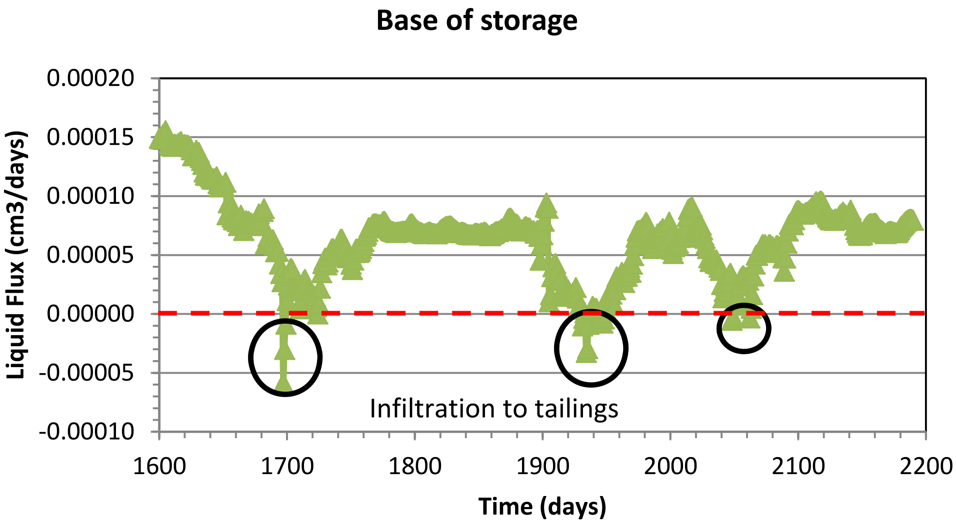


Figure 3-5 Example Water balance data for Scenario 2a.

3.3 Flux

The movement of water (liquid flux; cm^3/day) was estimate at the base of each layer within the cover and within the tailings (~0.5m from the top of the tailings). The results for each model simulation are displayed in Appendix III for year 4 to 6. Positive flux values indicate an upward movement of water, while a negative flux value represents a downward movement of water. An example is given below for scenario 2a (Figure 3-6). The example shows that the majority of water in the system is evaporating with only a small quantity of water infiltrating (Figure 3-1 and Figure 3-3). The topsoil layer shows the flux of water downward into the profile during the wet season (negative flux; infiltration) and generally a flux of water upwards in the dry season (i.e. positive flux); however, the volume of water movement in the topsoil is generally very low. The storage layer has a slight upward flux of water throughout most of the year, excluding a few instances in the wet season when precipitation is dominant. These few rainfall events results in very slight infiltration of water into the underlying layers. Excluding the rainfall events in the wet season, there is a general upward flux of water from the tailings into the storage layer, with a very slight movement of water into the topsoil.





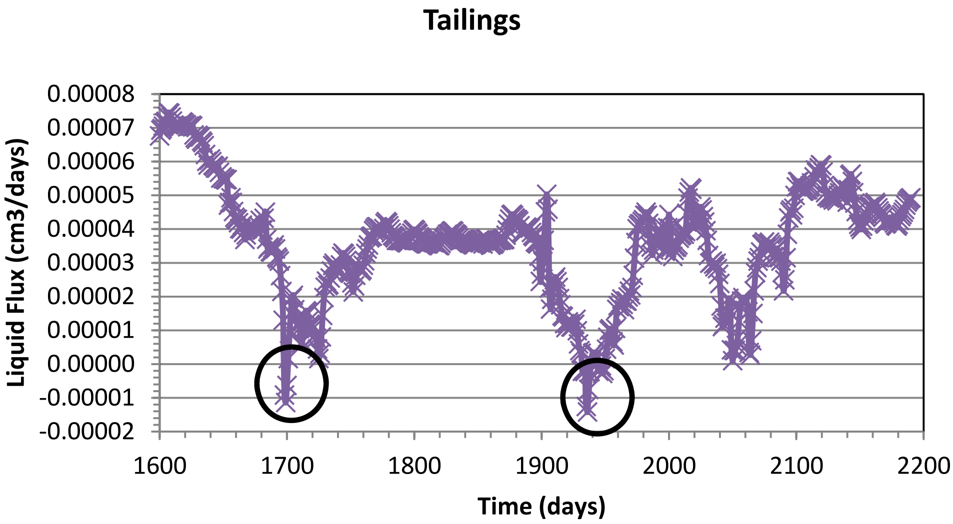


Figure 3-6 Example: Liquid flux for Scenario 2a (Type 1 with 1m storage layer); tailings Ksat = 1.00E-08 m/s.

The approximate net flux of water from the cover (directly above the tailings) to the tailings, and also into the tailings (~0.5 m) is presented in Table 3-1 for each scenario with a tailings K_{sat} = 1.00E-08 m/s; this provides a broad summary of all the scenario results. The corresponding results for the scenarios with a tailings K_{sat} = 1.00E-07 m/s are provided in Table 3-2. These results show that there is a very small/negligible flux of water into the tailings, due to the combination of the low conductivity tailings material, and the dry season climate which is favorable to evaporation over infiltration.

The approximate net flux of water at the base of each cover material for each cover type is summarised in Table 3-3, Table 3-4, and Table 3-5 for cover Type 1, Type 2 and Type 3, respectively. The general results for each scenario is summarised within the tables.

Table 3-1 Net total Water Flux into the tailings for year 5 -6

Scenario - Tailings saturated hydraulic conductivity; Ksat = 1.00E-08 m/s	Net Liquid Flux at top of tailings (cm^3) (year 5 - 6)	Net Liquid Flux within tailings (cm^3) (year 5 - 6)
Scenario 1a – Base case (no cover).	0.129	0.211
Scenario 2a – Type 1: vegetation; topsoil (15 cm); storage layer (1 m).	0.021	0.012
Scenario 3a – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m).	0.001	0.013
Scenario 4a – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm).	-0.003	0.054
Scenario 5a – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer.	0.021	0.009
Scenario 6a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m)	0.019	0.008
Scenario 7a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m)	0.023	0.009
Scenario 8a – Base case (no cover). Extreme event applied.	0.031	0.198
Scenario 9a – Type 1: vegetation; topsoil (15 cm); storage layer (1 m). Extreme event applied.	0.015	0.006
Scenario 10a – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m). Extreme event applied.	0.001	0.019
Scenario 11a – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm). Extreme event applied.	-0.001	0.044
Scenario 12a – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m). Extreme event applied.	0.020	0.008
Scenario 13a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m). Extreme event applied.	0.013	0.004
Scenario 14a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m). Extreme event applied.	0.016	0.005

Table 3-2 Net total Water Flux into the tailings for year 5 -6: revised tailings hydraulic conductivity

Scenario - Tailings saturated hydraulic conductivity; Ksat = 1.00E-07 m/s	Net Liquid Flux at top of tailings (cm^3) (year 5 - 6)	Net Liquid Flux within tailings (cm^3) (year 5 - 6)
Scenario 1b – Base case (no cover).	0.231	0.293
Scenario 2b – Type 1: vegetation; topsoil (15 cm); storage layer (1 m).	0.021	0.012
Scenario 3b – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m).	0.001	0.019
Scenario 4b – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm).	-0.027	0.406
Scenario 5b – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer.	0.021	0.009
Scenario 6b – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m)	0.019	0.008
Scenario 7b – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m)	0.023	0.010
Scenario 8b – Base case (no cover). Extreme event applied.	0.303	0.223
Scenario 9b – Type 1: vegetation; topsoil (15 cm); storage layer (1 m). Extreme event applied.	0.015	0.007
Scenario 10b – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m). Extreme event applied.	0.001	0.014
Scenario 11b – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm). Extreme event applied.	-0.037	0.422
Scenario 12b – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m). Extreme event applied.	0.020	0.009
Scenario 13b – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m). Extreme event applied.	0.013	0.005
Scenario 14b – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m). Extreme event applied.	0.016	0.005
Scenario 15 – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m). Extreme event applied.	0.024	0.010

Table 3-3 Cover Type 1 flux results summary for each cover layer

Tailings Ksat (m/s)	Scenarios - Type 1	Net, positive and negative Liquid Flux at base of layer (cm^3) (year 5 - 6)									Summary
		Topsoil flux			Storage flux			Tailings flux			
		Net	Net Upwards	Net Downwards	Net	Net Upwards	Net Downwards	Net	Net Upwards	Net Downwards	
1.00E-08	Scenario 2a – Type 1: vegetation; topsoil (15 cm); storage layer (1 m).	0.05	0.062	-0.011	0.051	0.052	-0.00006	0.026	0.026	0	Evaporation dominates infiltration. There is a net upward flux of water from the storage layer into the topsoil and from the tailings into the storage layer for all sensitivities. Decreasing the thickness of the storage layer to 10 cm results in minor infiltration of water to the tailings and a net downward movement of water through the storage layer. There is a larger net upward movement of water for the thicker 1 m storage layer, but a lower upward movement of water from the tailings.
	Scenario 3a – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m).	0.049	0.056	-0.006	0.001	0.001	0	0.046	0.046	0	
	Scenario 4a – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm).	0.06	0.061	-0.003	-0.004	0.001	-0.005	0.14	0.14	-0.001	
	Scenario 9a – Type 1: vegetation; topsoil (15 cm); storage layer (1 m). Extreme event applied.	0.033	0.046	-0.012	0.035	0.035	0	0.014	0.014	0	
	Scenario 10a – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m). Extreme event applied.	0.032	0.039	-0.007	0.002	0.002	0	0.032	0.032	0	
	Scenario 11a – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm). Extreme event applied.	0.039	0.043	-0.003	-0.002	0.001	-0.003	0.11	0.11	-0.001	
1.00E-07	Scenario 2b – Type 1: vegetation; topsoil (15 cm); storage layer (1 m).	0.021	0.028	-0.007	0.021	0.021	-0.00012	0.01	0.012	-0.00005	The results are the same as for tailings with a Ksat = 1.00E-08 m/s; however, generally the flux values in each direction are slightly larger. There is also a negative flux value for the storage layer in scenario 10b representing infiltration to the tailings.
	Scenario 3b – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m).	0.020	0.024	-0.004	0.001	0.001	0	0.02	0.019	-0.0000002	
	Scenario 4b – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm).	0.042	0.042	-0.00006	-0.027	0.001	-0.028	0.41	0.406	0	
	Scenario 9b – Type 1: vegetation; topsoil (15 cm); storage layer (1 m). Extreme event applied.	0.014	0.021	-0.007	0.015	0.015	0	0.01	0.007	0	
	Scenario 10b – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m). Extreme event applied.	0.014	0.017	-0.004	0.001	0.001	0	0.01	0.014	0	
	Scenario 11b – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm). Extreme event applied.	0.030	0.030	-0.00001	-0.037	0.005	-0.042	0.42	0.422	0	

Table 3-4 Cover Type 2 flux results summary for each cover layer

Tailings Ksat (m/s)	Scenarios - Type 2	Net Liquid Flux at base of layer (cm^3) (year 5 - 6)												Summary
		Topsoil flux			Storage flux			Compacted tailings flux			Tailings flux			
		Net	Net Upwards	Net Downwards	Net	Net Upwards	Net Downwards	Net	Net Upwards	Net Downwards	Net	Net Upwards	Net Downwards	
1.00E-08	Scenario 5a – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m).	0.021	0.028	-0.007	0.023	0.023	0	0.021	0.021	0	0.009	0.009	0	Evaporation dominates infiltration. There is a net upward flux of water from the storage layer into the topsoil and from the tailings to the storage layer for all sensitivities. There is no net movement of water down through the storage layer, compacted tailings or tailings. There is a slight downward movement of water from the topsoil to the storage layer.
	Scenario 12a – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m). Extreme event applied.	0.021	0.028	-0.007	0.022	0.022	0	0.020	0.020	0	0.008	0.008	0	
1.00E-07	Scenario 5b – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m).	0.021	0.028	-0.007	0.023	0.023	0	0.021	0.021	0	0.009	0.009	0	The results are the same as for tailings with a Ksat = 1.00E-08 m/s.
	Scenario 12b – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m). Extreme event applied.	0.021	0.028	-0.007	0.022	0.022	0	0.020	0.020	0	0.009	0.009	0	

Table 3-5 Cover Type 3 flux results summary for each cover layer

Tailings Ksat (m/s)	Scenarios - Type 3	Net Liquid Flux at base of layer (cm^3) (year 5 - 6)												Summary
		Topsoil Flux			Storage Flux			Capillary Break Flux			Tailings Flux			
		Net	Net Upwards	Net Downwards	Net	Net Upwards	Net Downwards	Net	Net Upwards	Net Downwards	Net	Net Upwards	Net Downwards	
1.00E-08	Scenario 6a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m)	0.021	0.028	-0.007	0.022	0.022	0	0.019	0.019	0	0.008	0.008	0	Evaporation dominates infiltration. There is a net upward flux of water from the storage layer into the topsoil, from the capillary break into the storage layer and from the tailings into the capillary break for all sensitivities. There is only a slight flux of water downwards through the topsoil into the storage layer.
	Scenario 7a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m)	0.024	0.028	-0.003	0.029	0.029	0	0.023	0.023	0	0.009	0.009	0	
	Scenario 13a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m). Extreme event applied.	0.014	0.021	-0.007	0.016	0.016	0	0.013	0.013	0	0.004	0.004	0	
	Scenario 14a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m). Extreme event applied.	0.017	0.021	-0.004	0.022	0.022	0	0.016	0.016	0	0.005	0.005	0	
1.00E-07	Scenario 6a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m)	0.021	0.028	-0.007	0.022	0.022	-0.00001	0.019	0.019	-0.000001	0.008	0.008	-0.00001	The results are close to identical to the tailings with a Ksat = 1.00E-08 m/s. Scenario 15 includes a capillary break with a Ksat = 1.00E-03 m/s, which shows to be ineffective at preventing capillary rise of water into the storage layer.
	Scenario 7a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m)	0.024	0.028	-0.003	0.029	0.029	0	0.023	0.023	0	0.010	0.010	0	
	Scenario 13a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m). Extreme event applied.	0.024	0.021	-0.007	0.029	0.016	0	0.024	0.013	0	0.005	0.005	0	
	Scenario 14a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m). Extreme event applied.	0.017	0.021	-0.004	0.022	0.022	0	0.016	0.016	0	0.005	0.005	0	
	Scenario 15 – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m).	0.024	0.028	-0.003	0.029	0.029	0	0.024	0.024	0	0.010	0.010	0	

4 CONCLUSIONS/INTERPRETATIONS

The following conclusions/interpretations can be drawn from the Vadose/W modelling results:

- The system is dominated by evaporation over infiltration for all the scenarios, reflecting the dry season climate. As a result, only small quantities of water enter the system (cover domain).
- There is a general net upward movement of water from the tailings through the cover profile for all the cover types and scenarios (sensitivities).
- Although there is a net upward movement of water from the storage layer to the topsoil for all cover types, there are also instances of downward movement of water from the topsoil to the storage layer for all sensitivities, although a much smaller flux.
- The downward flux of water from the topsoil is retained in the storage layer for the majority of simulations. This excludes cover Type 1 with a 10 cm storage layer – for these simulations the net flux of water is negative representing a downward movement of water into the tailings.
- The flux of water into the tailings layer is very low or negligible for all the cover types and scenarios. For the scenarios where Infiltration to the tailings occurs, this only occurs intermittently in the wet season.
- The combination of the low conductivity tailings material, and dry season climate, limits the overall cover infiltration.
- Increasing the thickness of the storage layer results in a lower net flux of water out of the tailings and through the topsoil layers, but generally a higher upward flux of water through the storage layer.
- Based on the cover types modelled, there is little benefit in compacting or other amending the tailings due to the already low permeability of the tailings. The tailings permeability ultimately acts as the limiting factor for the downward flux into the tailings.
- Including a capillary break in the cover slightly reduces the upward movement of water from the tailings; however the capillary break does not entirely prevent the upward movement of water. Based on these results (assuming the capillary break properties used in this modelling), there is little benefit in including a capillary break in the cover, unless a capillary break configuration is identified (i.e. thickness, hydraulic parameter) that could mitigate the upward flux from the tailings.
- Very limited water losses from the cover were observed via transpiration through plant uptake for each of the simulated vegetated cover options.
- In general, the Type 1 and Type 2 cover options (not including scenarios with the 10 cm thick storage layer) provide the most effective profiles for mitigating downward flux into the tailings. The capillary break incorporated into the Type 3 cover option was ineffective at mitigating capillary rise from the tailings using the model parameters adopted during this study. The majority of scenarios from all three cover options simulated a net upward flux through the cover profile. However, the results from the Vadose/W modelling did not confirm if the upward flux from the storage or topsoil layer (Type 1 and 2) had originated

from the tailings or is a result of previous rainfall infiltration. Further characterisation of the upward flux is required to confirm potential capillary rise of tailings contact water to the root-zone / ground surface. Additional simulations focusing on the capillary break configurations should also be undertaken to identify a cover option to mitigate the upward flux from the tailings

5 CLOSING

This report is an instrument of service of Klohn Crippen Berger Ltd. The draft letter report has been prepared for the exclusive use of Northern Minerals Limites for the specific application to the Browns Range Project. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavored to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Matt Landers
Geochemist
Australasian Operations

Chris Strachotta
Associate & Manager – Western Australia
Australasian Operations

REFERENCES

BOM (2013) Australian Governments Bureau of Meteorology. .
http://www.bom.gov.au/climate/data/index.shtml.

Golder (2014) Preliminary Geotechnical Investigation Report – Stage 1: Browns Range Project.

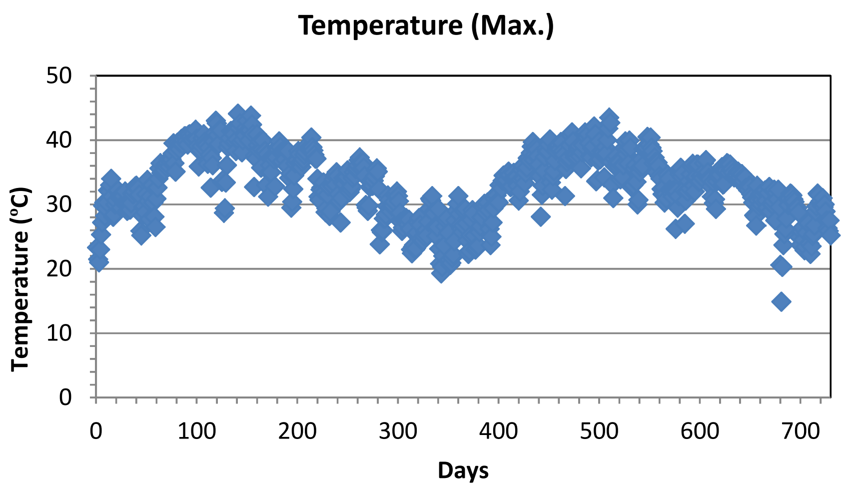
Golder (2013) Tailings Geotechnical and Rheological Laboratory Testing.

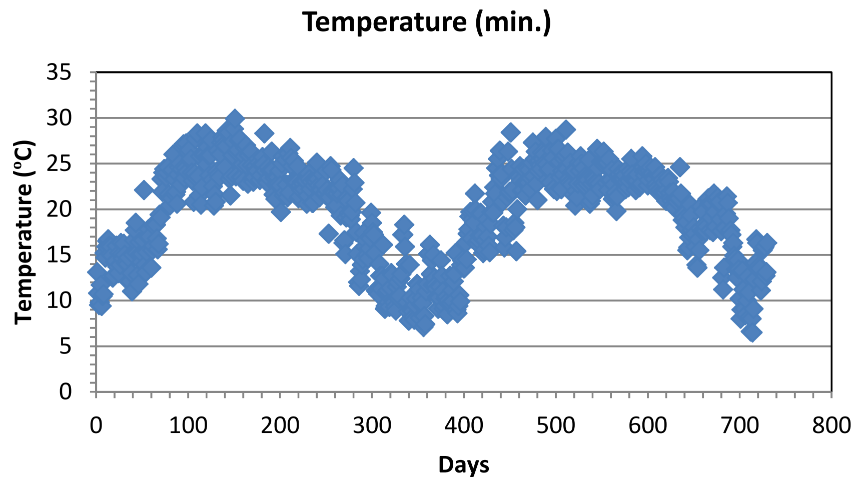
Outback Ecology (MWH Australia) (2014a) Analogue Slopes: Soil and Vegetation Assessment.

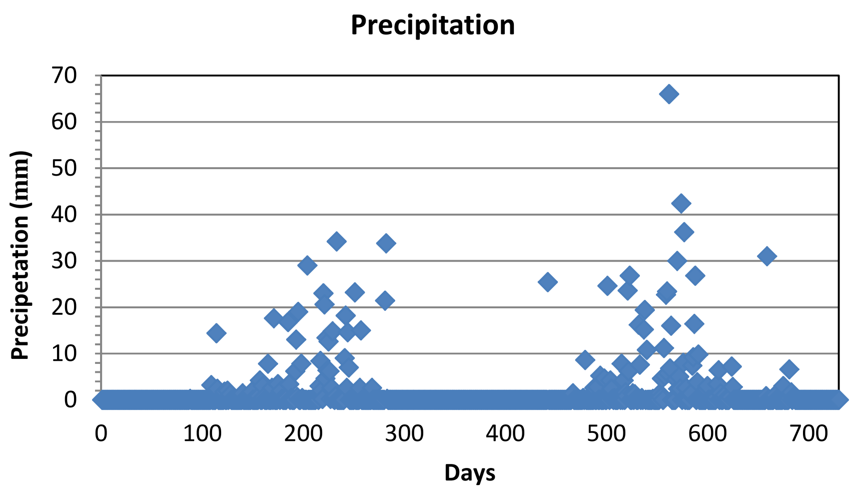
Outback Ecology (MWH Australia) (2014b) Baseline Soils and Landform Assessment.

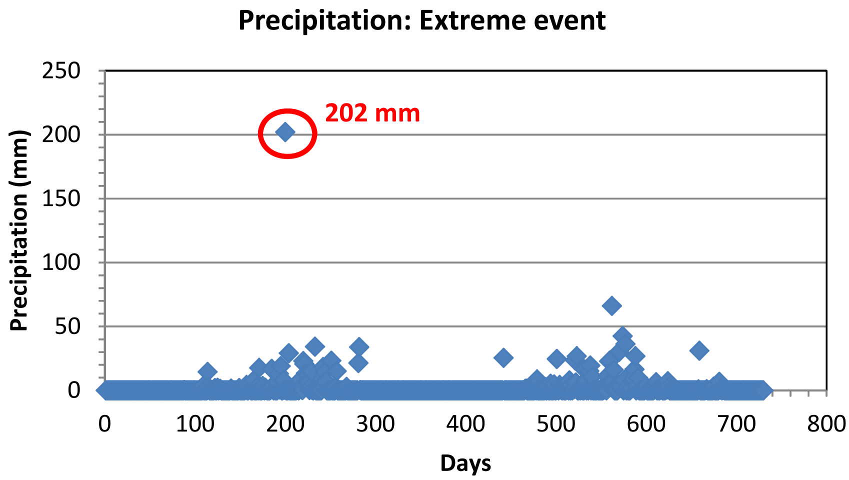
APPENDIX I

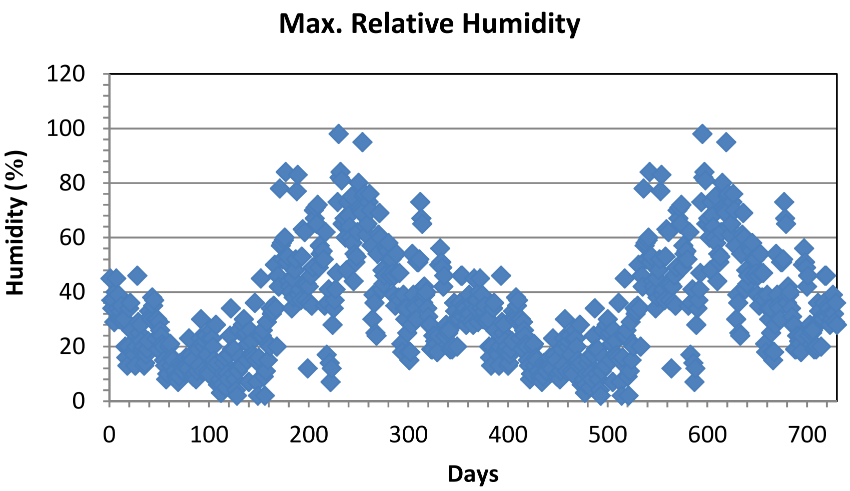
Climate Conditions for Vadose Modelling

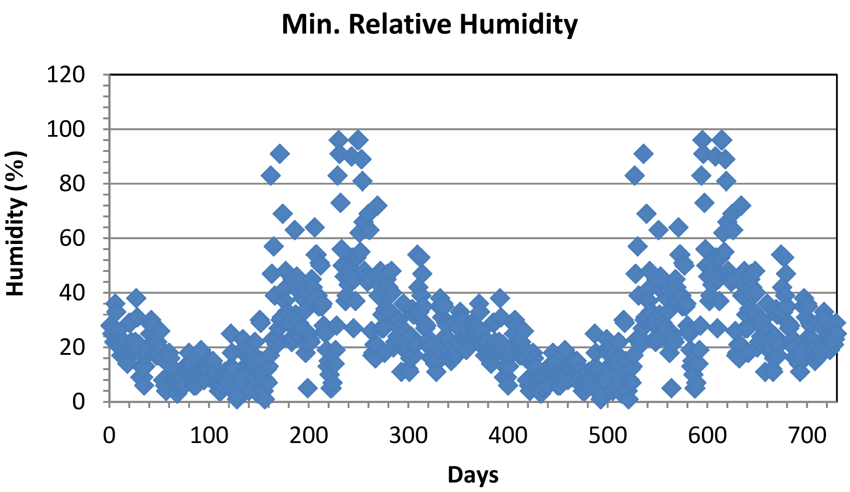

Temperature (Max.)
Temperature (°C)
50
40
30
20
10
0
0
100
200
300
400
500
600
700
Days

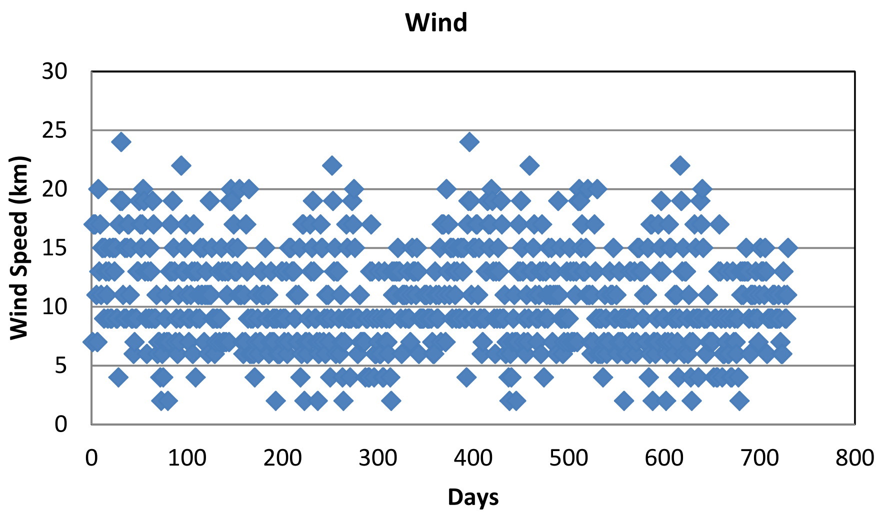

Temperature (min.)
Temperature (°C)
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
Days


Precipitation
Precipetation (mm)
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
Days


Precipitation: Extreme event
202 mm
Precipitation (mm)
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
Days


Max. Relative Humidity
Humidity (%)
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
Days


Min. Relative Humidity
Humidity (%)
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
Days


Wind
Wind Speed (km)
30
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
Days

APPENDIX II

Vadose Modelling: Vegetation Influence

The influence of vegetation on infiltration and evapotranspiration is a variable that can be applied to the surface of the Vadose/W profile to represent re-vegetated conditions. This involves three separate functions to represent the leaf area index, the permanent wilting point, and the root depth and structure.

THE LEAF AREA INDEX

The leaf area index is a measure of the one-sided green leaf area per unit ground surface area in broadleaf canopies. The planned plant species at closure are not currently known; therefore the following species were used as analogues:

- Pennisetum clandestinum (Kikuyu grass);
- Trifolium repens (White Clover); and,
- Calopogonium mucunoides (wild ground nut).

These species are expected to establish fully within one to two years of planting.

The leaf area index function was developed to mimic a relatively quick establishment of vegetation on the NOEF cover material with full coverage after two years of growth (Figure IV.0-1).

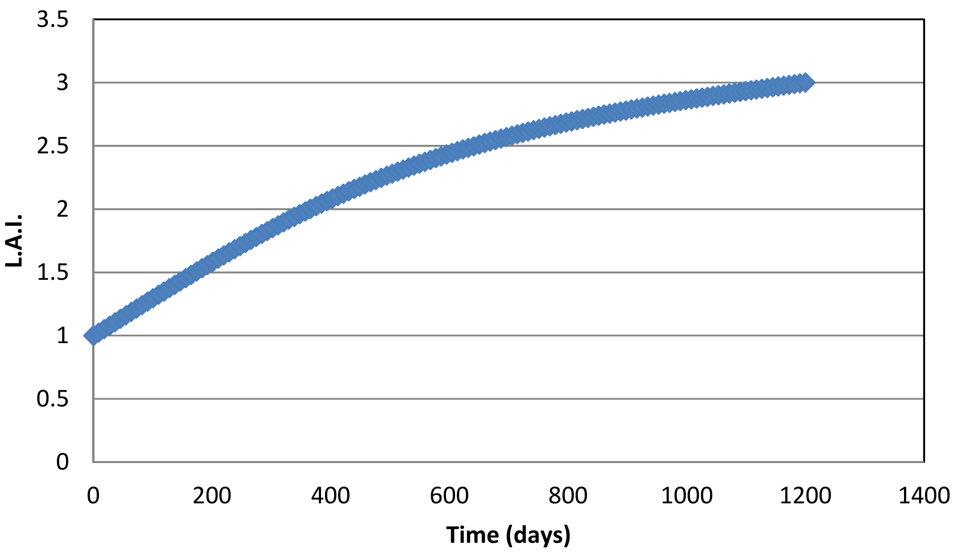


Figure IV.0-1 Leaf Area Index Function Used for HVJV Closure Plant Species

The Permanent Wilting Point

The permanent wilting point, or plant moisture limiting factor is described by the function in Figure IV.0-2. This variable accounts for the dieback of vegetation from exceedingly dry periods where the matric suction reaches points where plant growth will be limited. The standard Vadose/W created curve for a permanent wilting point at 1500 kPa is used in this case. It is unlikely that material properties in the growth medium layer of material will reach this point under the climate conditions present on site.

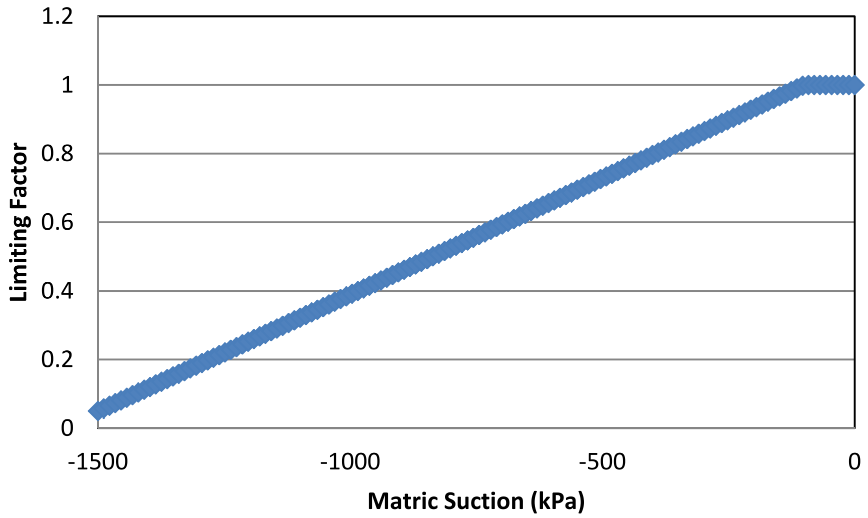


Figure IV.0-2 Plant Limiting Function Developed by Vadose/W for PWP at 1500 kPa

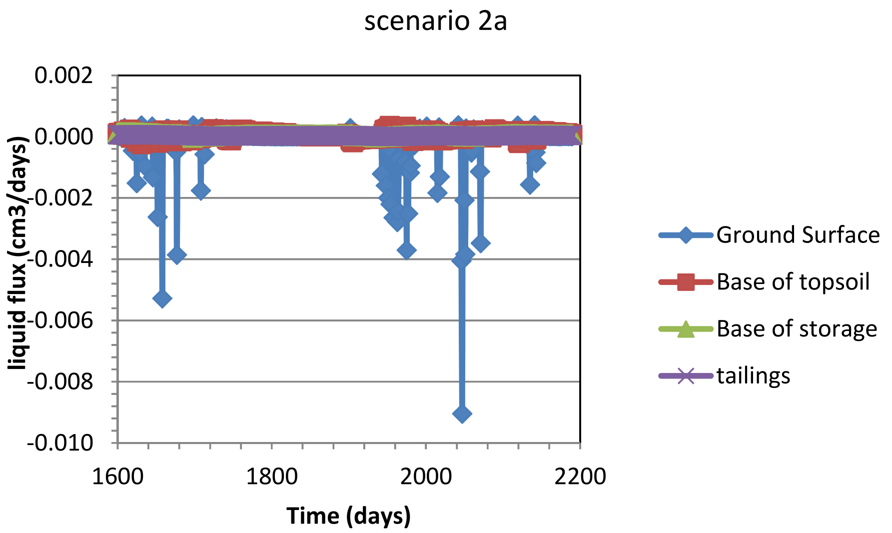
Rooting Depth

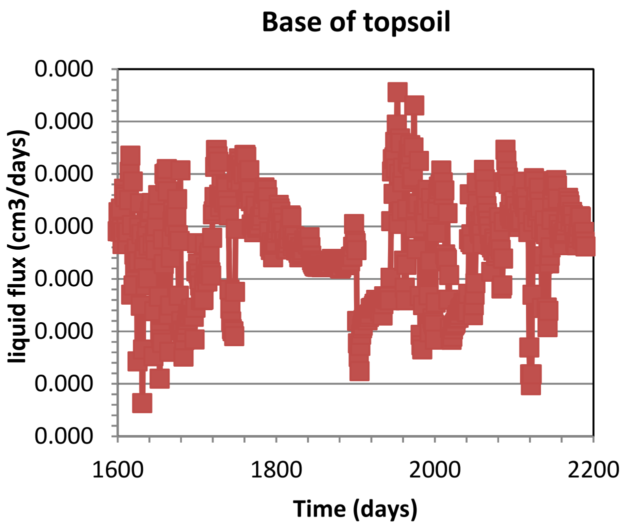
The expected rooting depth of the primary re-vegetation legumes are within the 50 cm top layer of soil applied to the erosion resistant surface cover. The expected rooting depth is between 10 cm and 40 cm for the species mentioned above. Secondary species are expected to maintain a relatively shallow rooting depth and expand laterally to make the most use of surface available nutrients. It would not be uncommon however for these species to reach rooting depths between 50 cm and 200 cm. A general rooting depth for the Vadose/W modelling was kept between 20 cm and 50 cm for the shallow rooting species and up to 200 cm for the deeper rooting species.

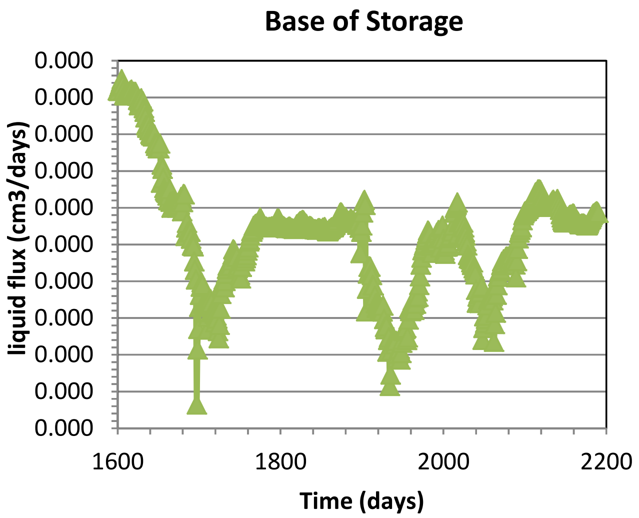
APPENDIX III

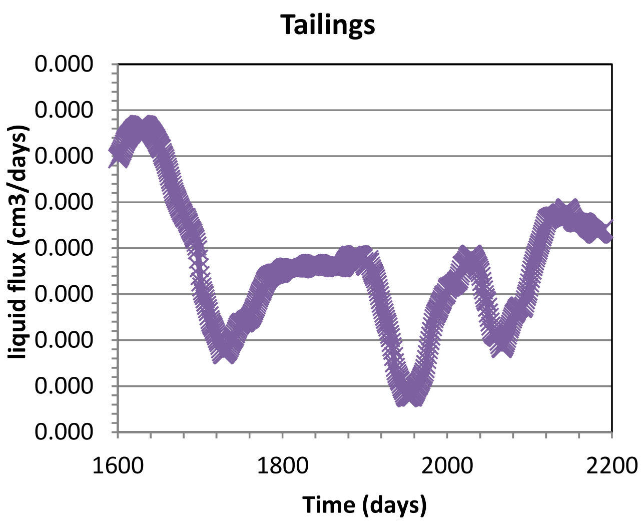
Vadose Modelling Results

Scenario 2a – Type 1: vegetation; topsoil (15 cm); storage layer (1 m).

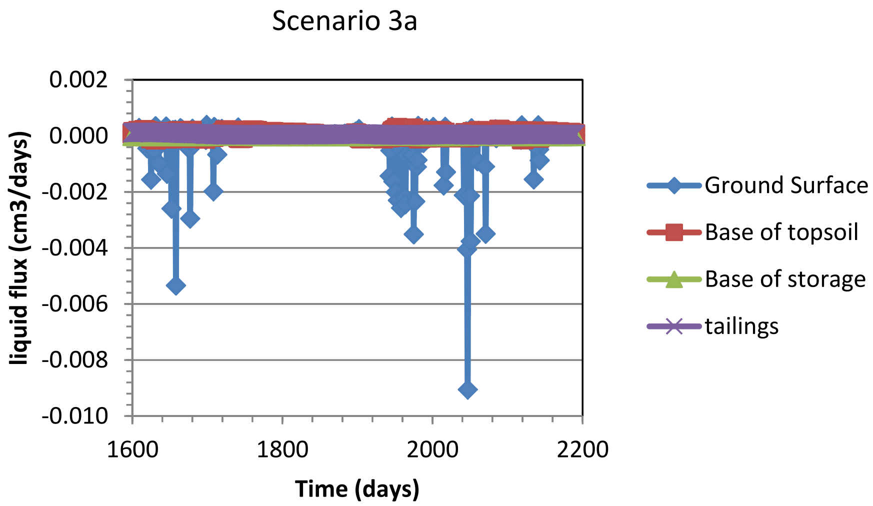


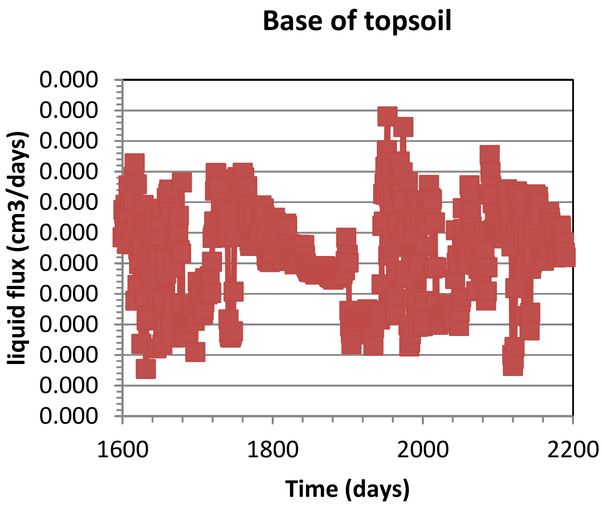


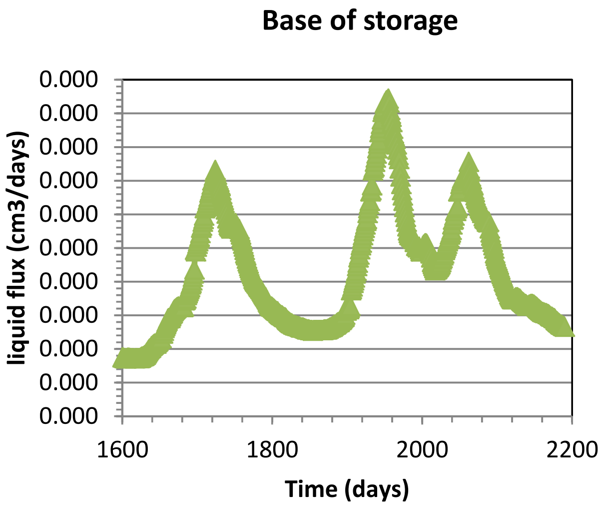

Base of Storage
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
liquid flux (cm3/days)
1600
1800
2000
2200
Time (days)

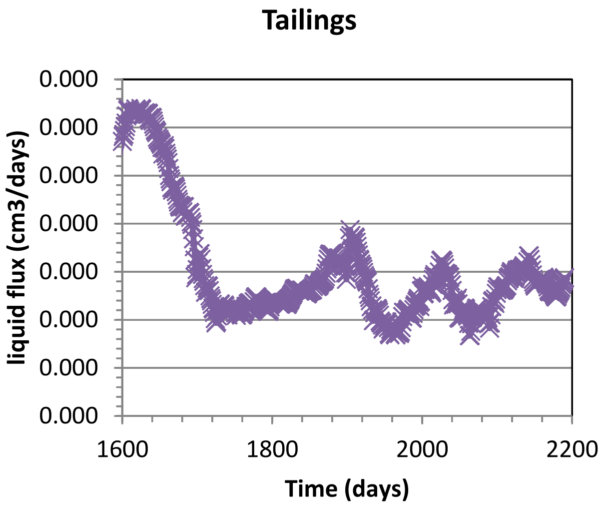

Tailings
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
liquid flux (cm3/days)
1600
1800
2000
2200
Time (days)

Scenario 3a – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m).

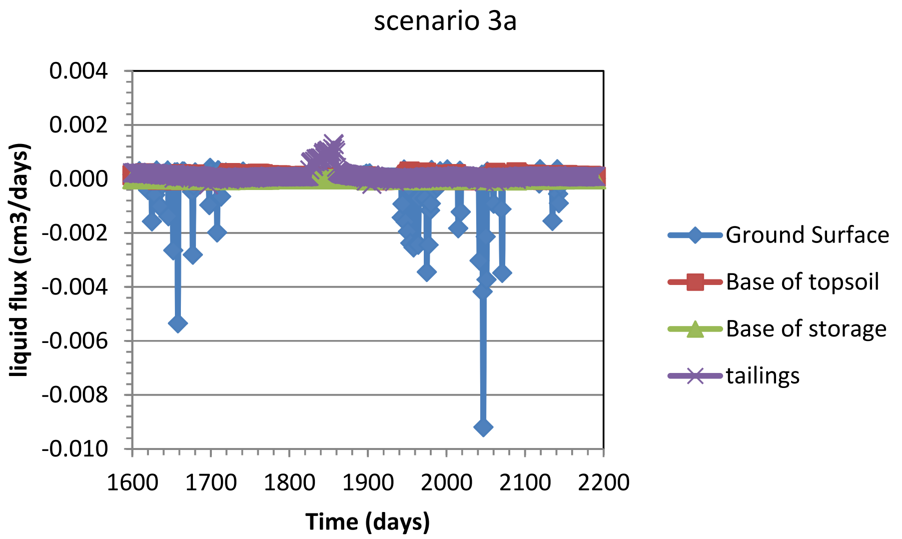


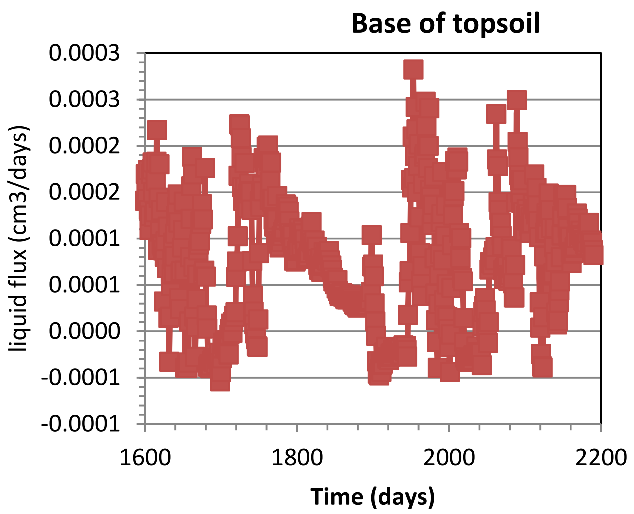


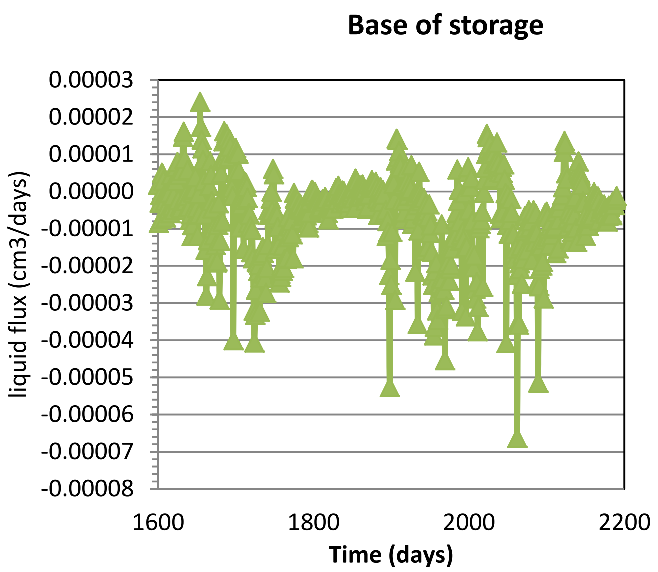

Base of storage
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
liquid flux (cm3/days)
1600
1800
2000
2200
Time (days)

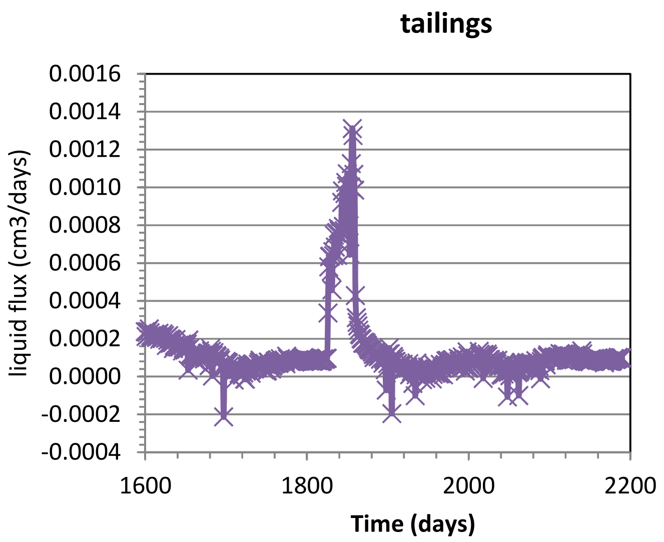

Tailings
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
liquid flux (cm3/days)
1600
1800
2000
2200
Time (days)

Scenario 4a – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm).

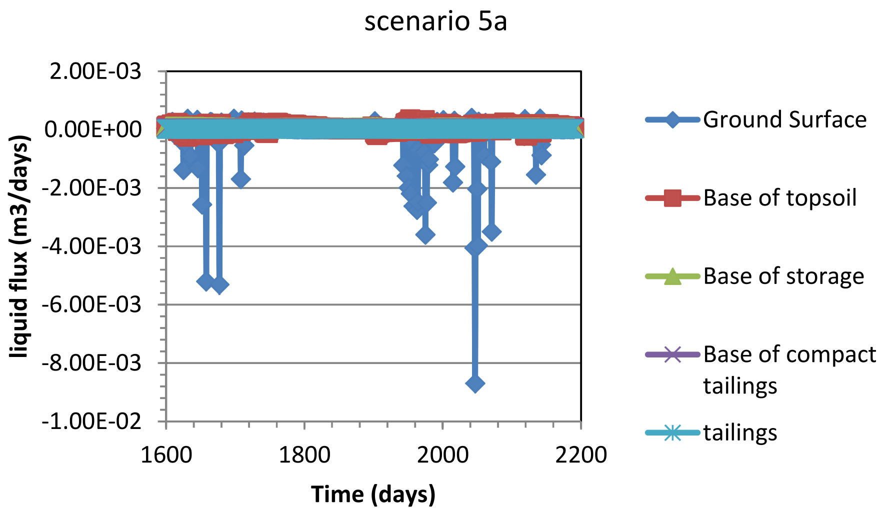


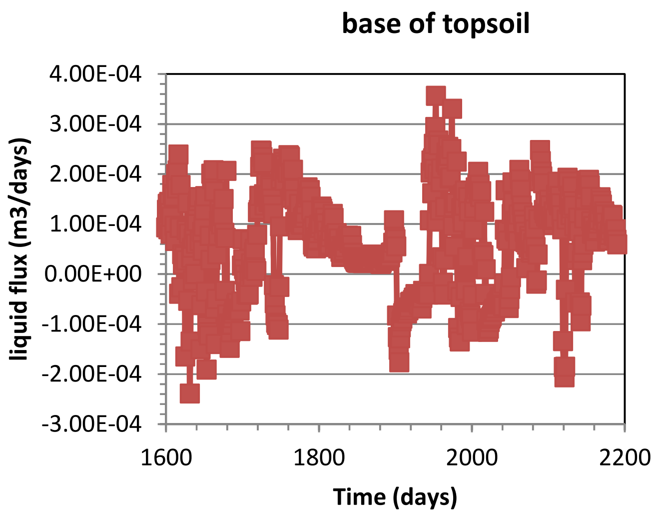


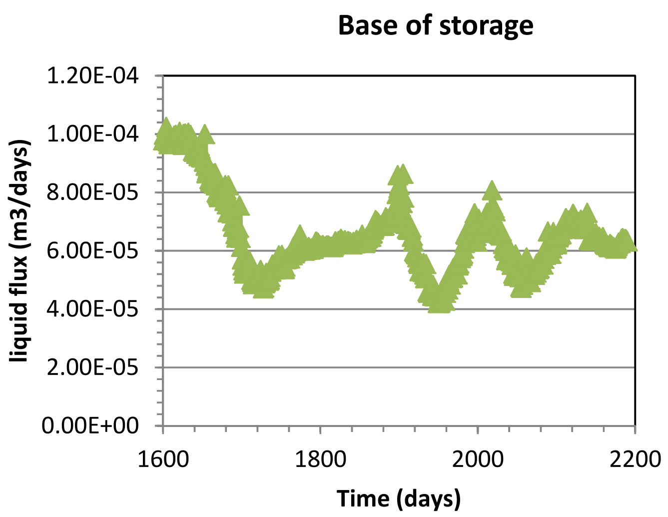

Base of storage
liquid flux (cm3/days)
0.00003
0.00002
0.00001
0.00000
-0.00001
-0.00002
-0.00003
-0.00004
-0.00005
-0.00006
-0.00007
-0.00008
1600
1800
2000
2200
Time (days)

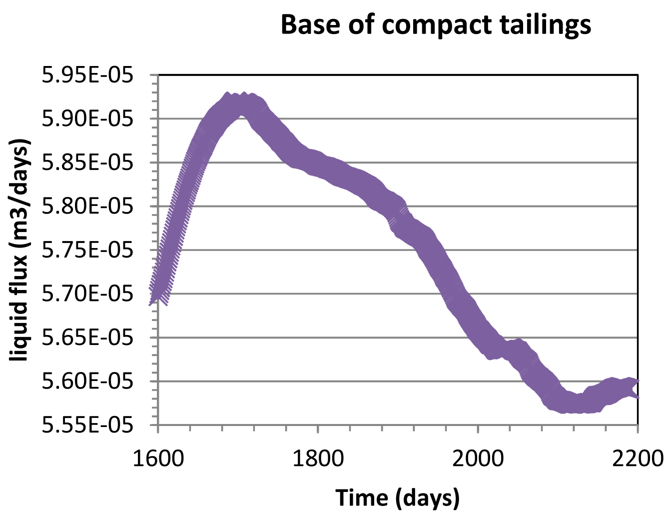

tailings
liquid flux (cm3/days)
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
-0.0002
-0.0004
1600
1800
2000
2200
Time (days)

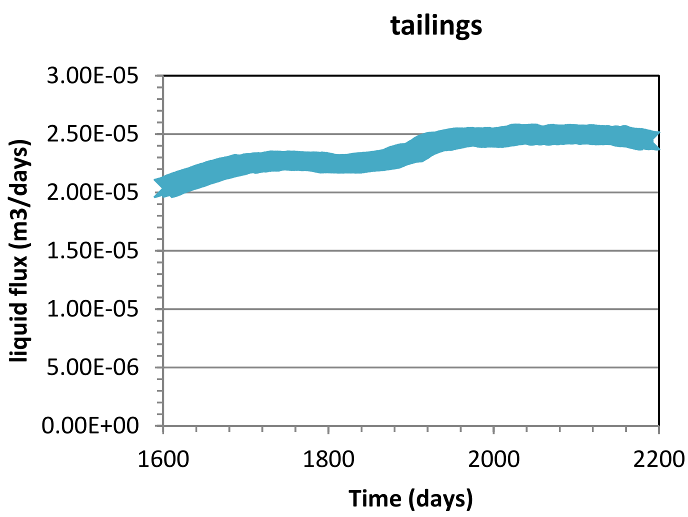
Scenario 5a – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m).



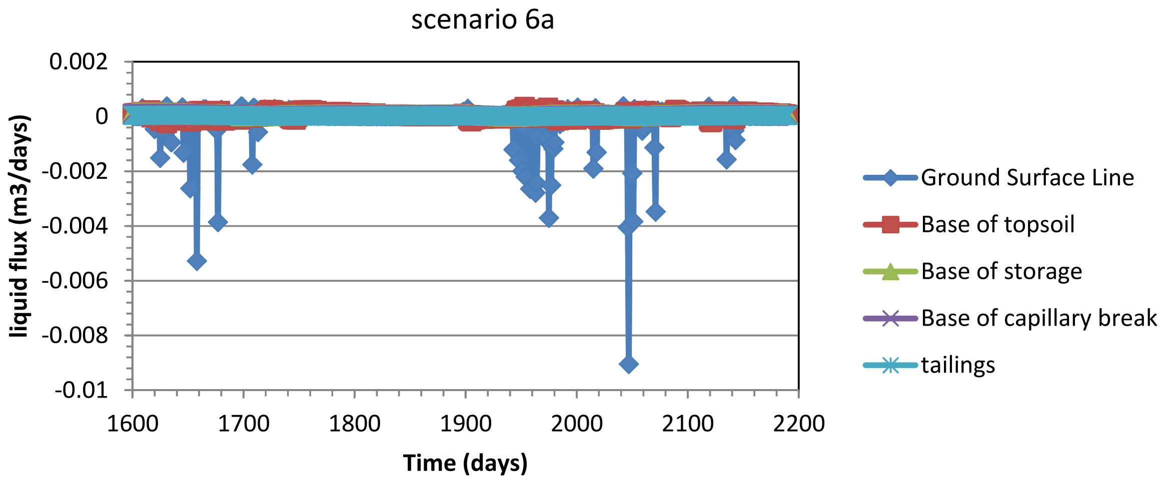


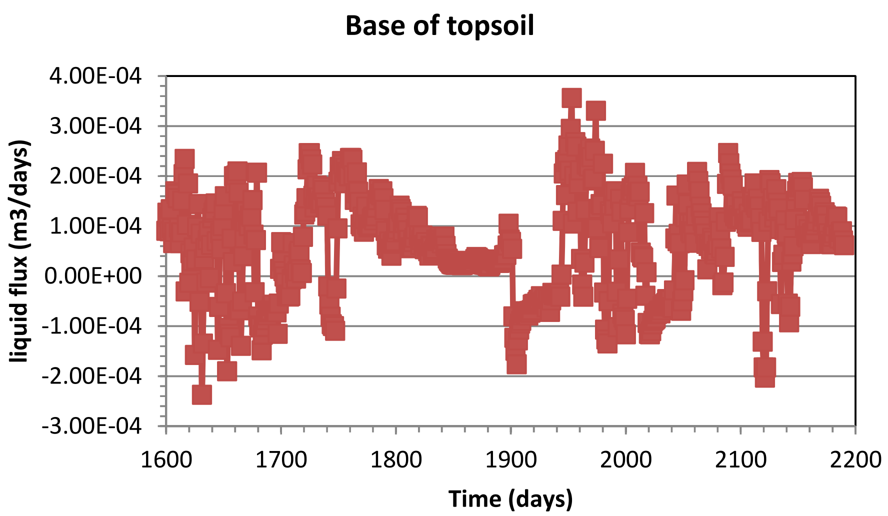

Base of storage
liquid flux (m3/days)
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
1600
1800
2000
2200
Time (days)

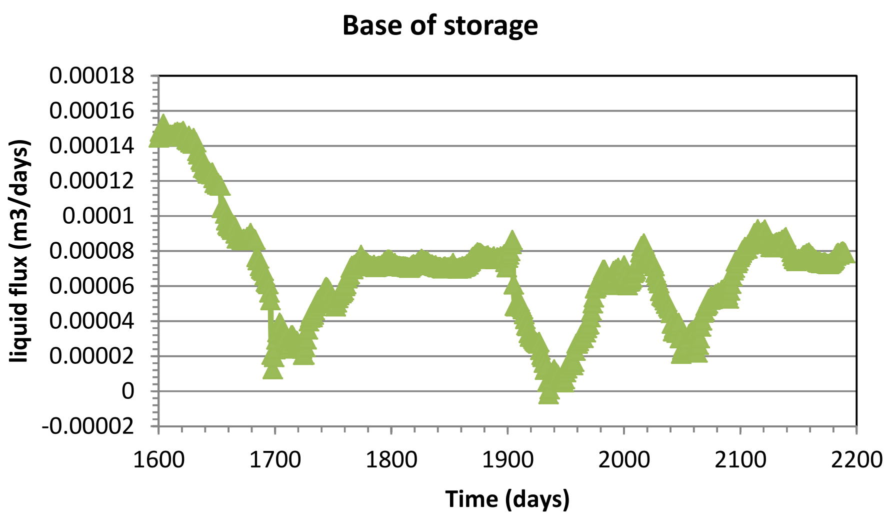

Base of compact tailings
liquid flux (m3/days)
5.95E-05
5.90E-05
5.85E-05
5.80E-05
5.75E-05
5.70E-05
5.65E-05
5.60E-05
5.55E-05
1600
1800
2000
2200
Time (days)

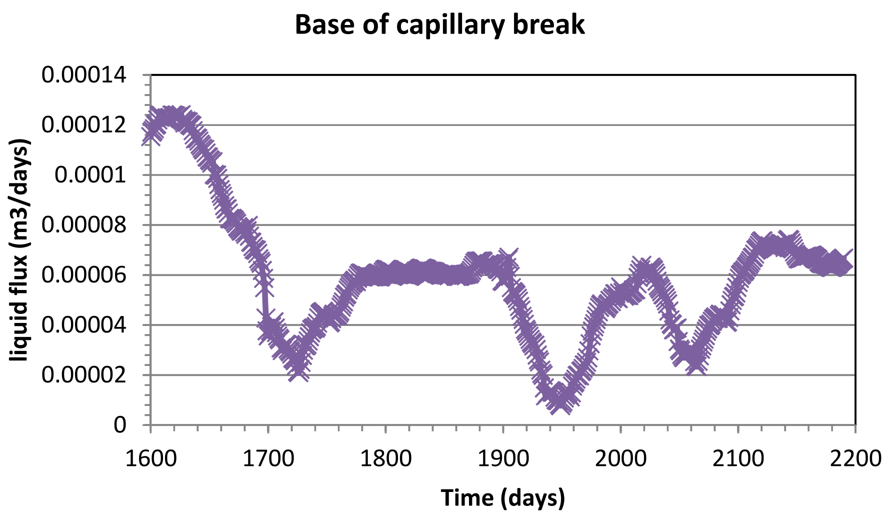

tailings
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
liquid flux (m3/days)
1600
1800
2000
2200
Time (days)

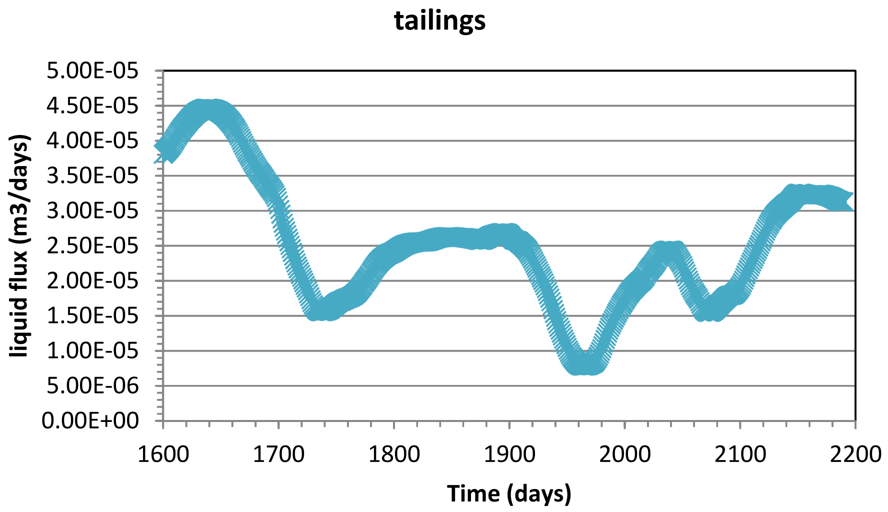
Scenario 6a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m)



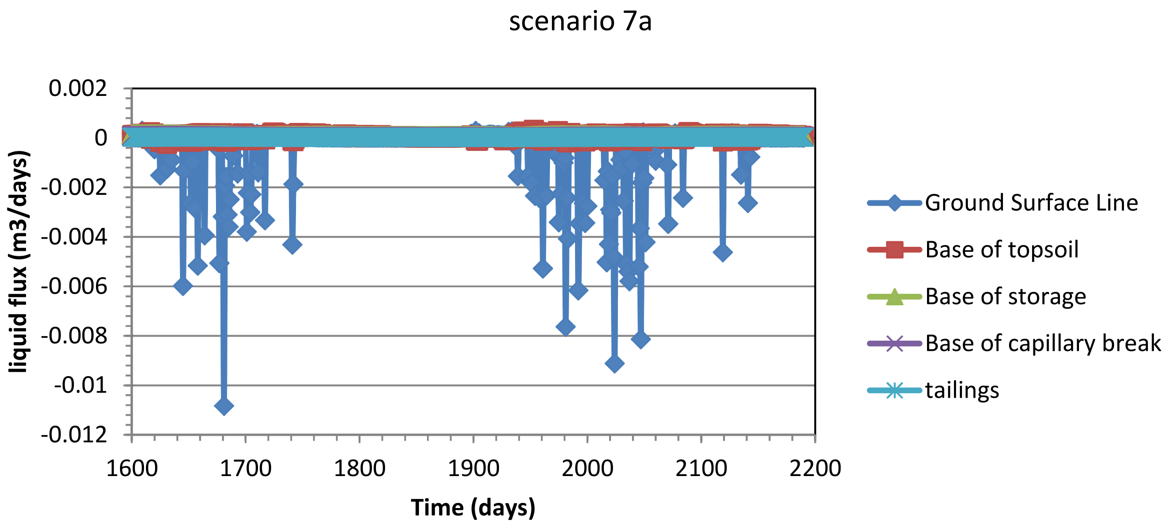


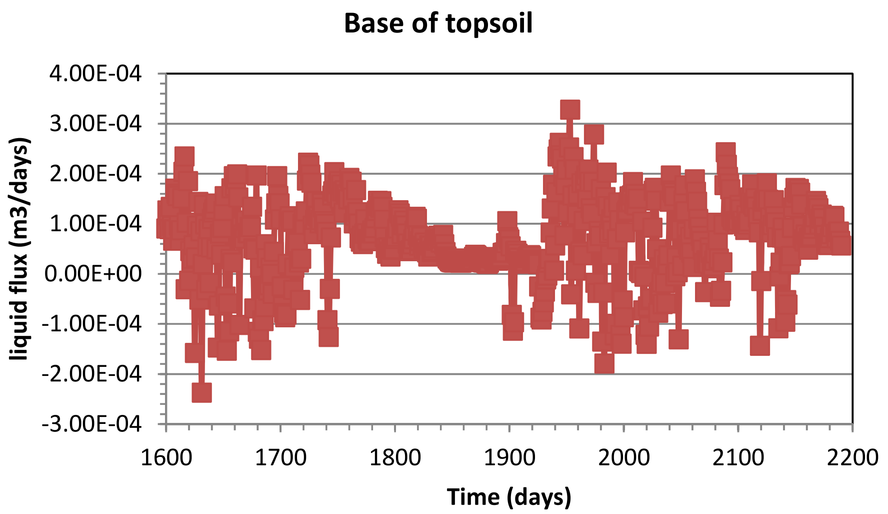

Base of storage
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
-0.00002
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

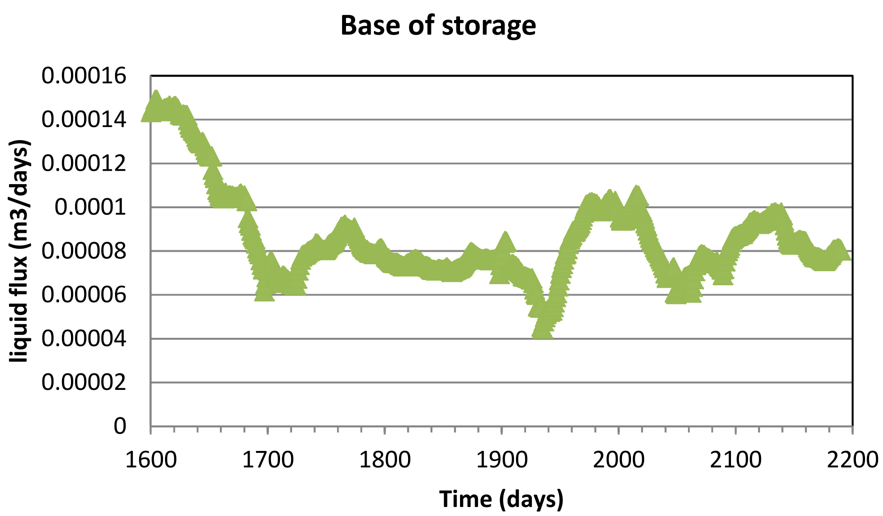

Base of capillary break
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

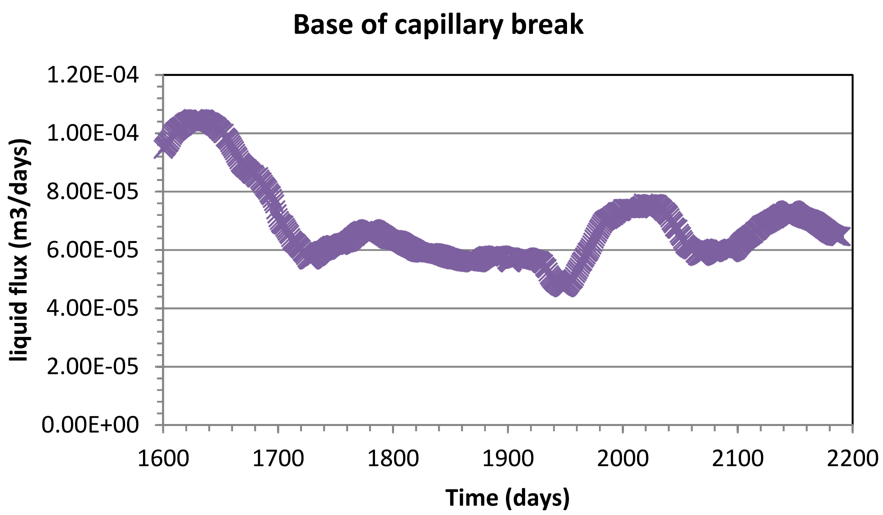

tailings
5.00E-05
4.50E-05
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

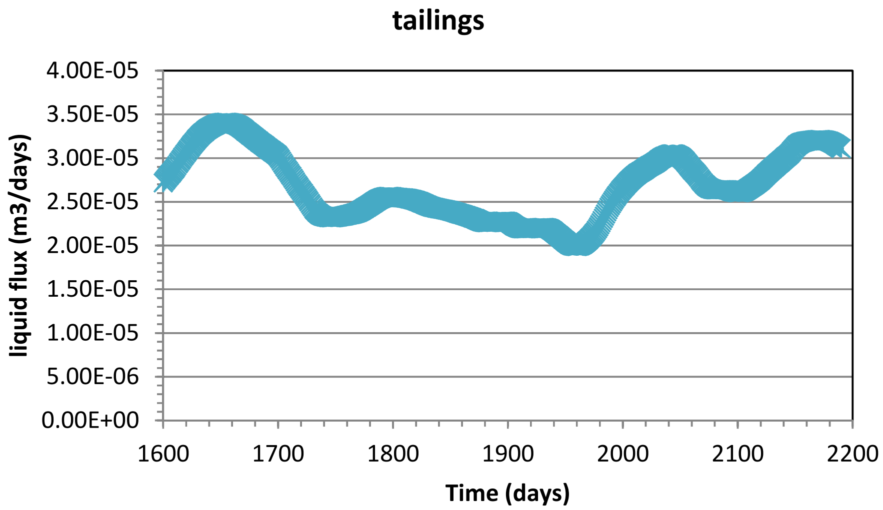
Scenario 7a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m)



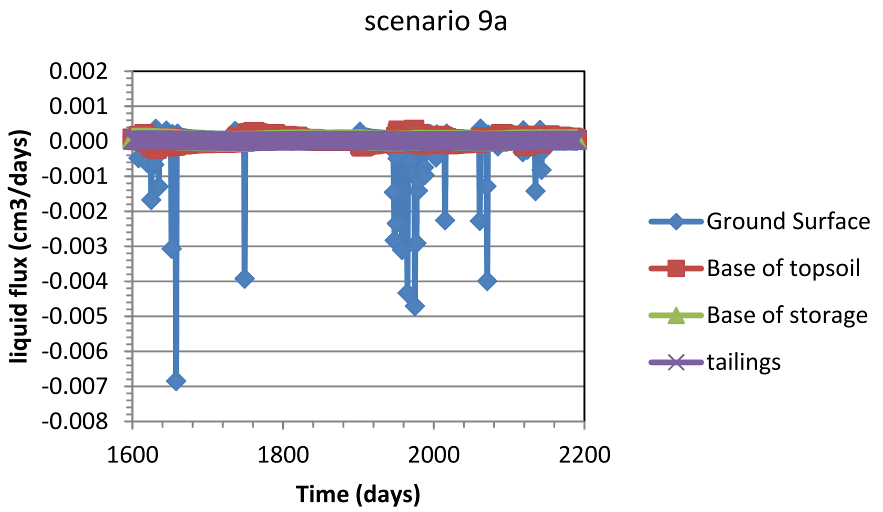


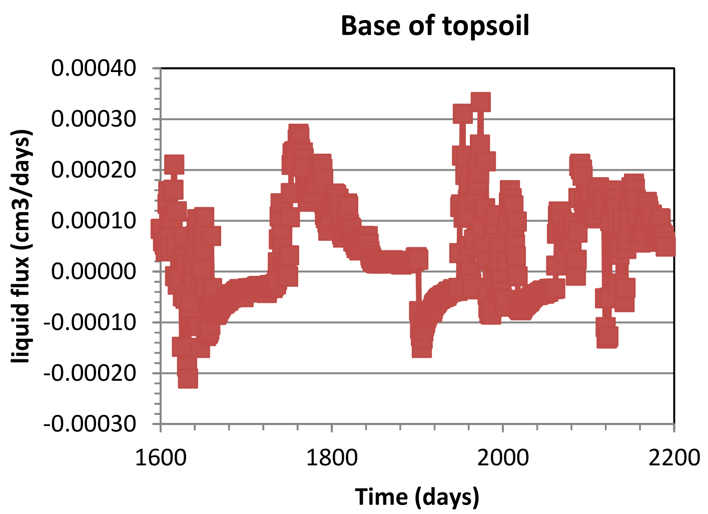

Base of storage
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

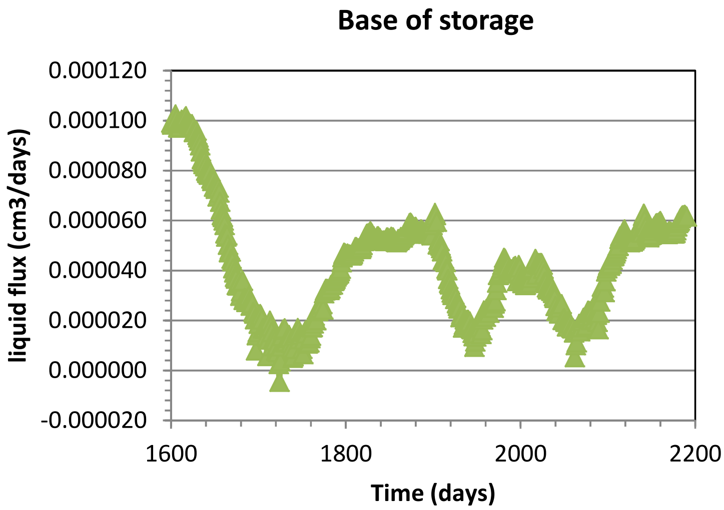

Base of capillary break
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

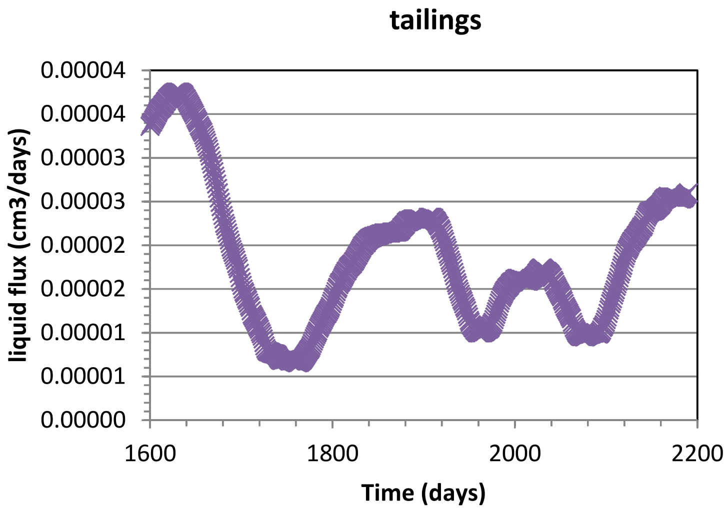

tailings
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

Scenario 9a – Type 1: vegetation; topsoil (15 cm); storage layer (1 m). Extreme event applied.

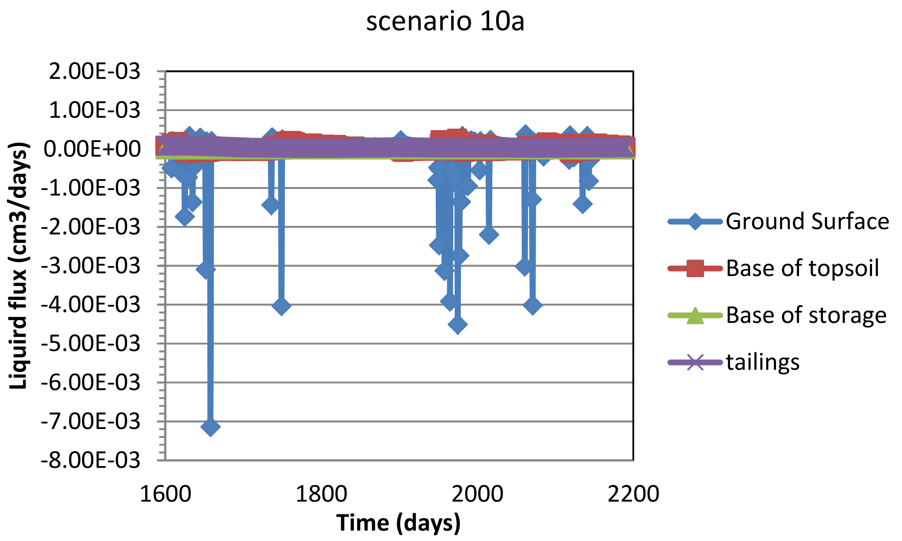


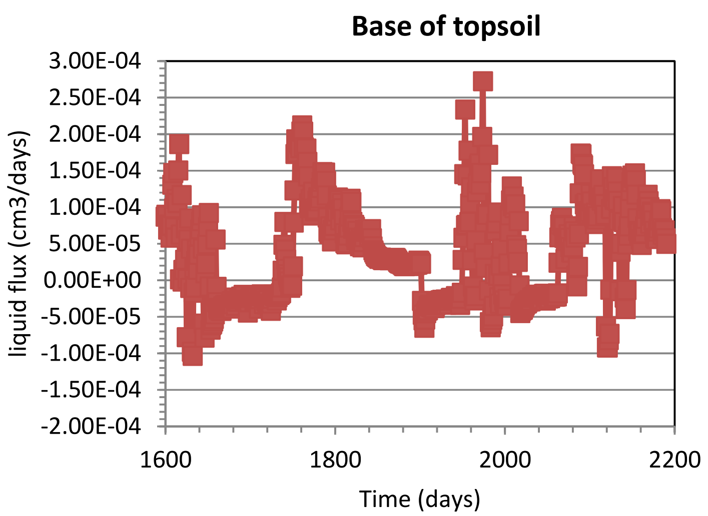


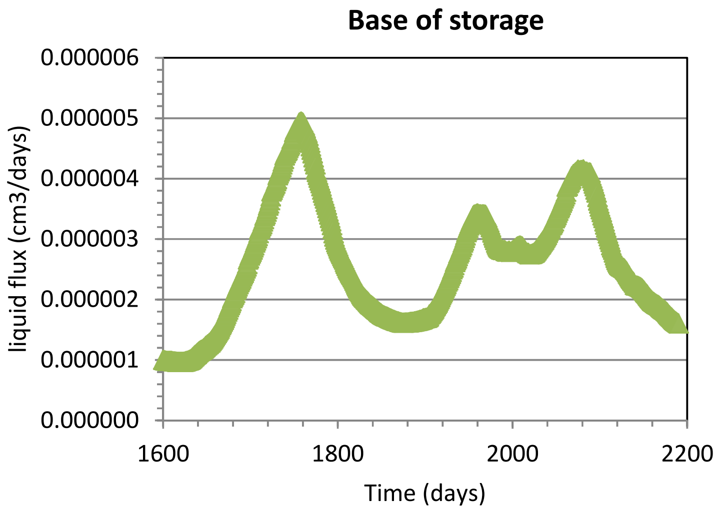

Base of storage
liquid flux (cm3/days)
0.000120
0.000100
0.000080
0.000060
0.000040
0.000020
0.000000
-0.000020
1600
1800
2000
2200
Time (days)

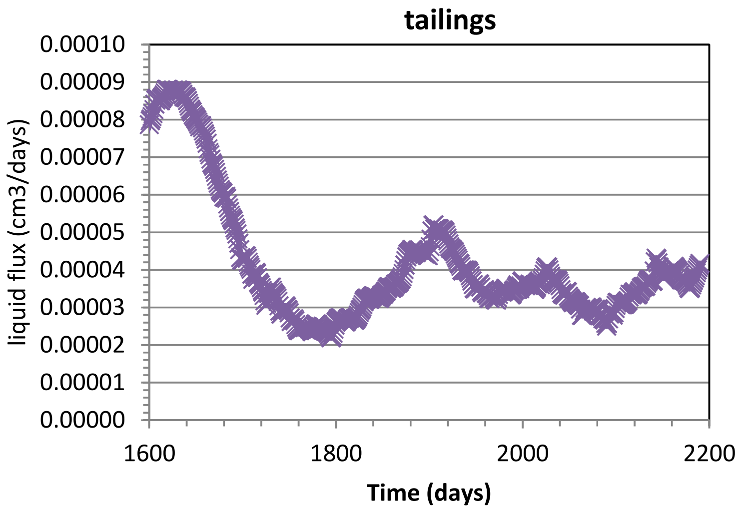

tailings
liquid flux (cm3/days)
0.00004
0.00004
0.00003
0.00003
0.00002
0.00002
0.00001
0.00001
0.00000
1600
1800
2000
2200
Time (days)

Scenario 10a – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m). Extreme event applied.

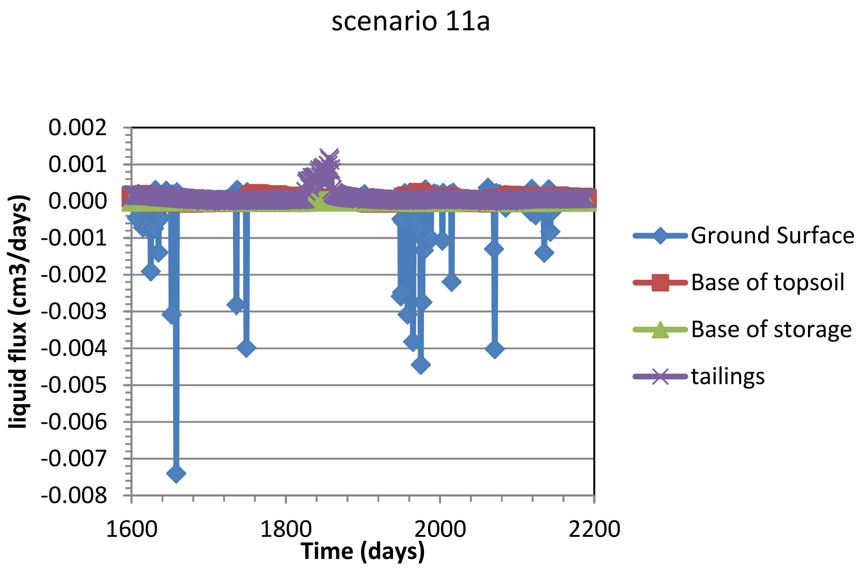


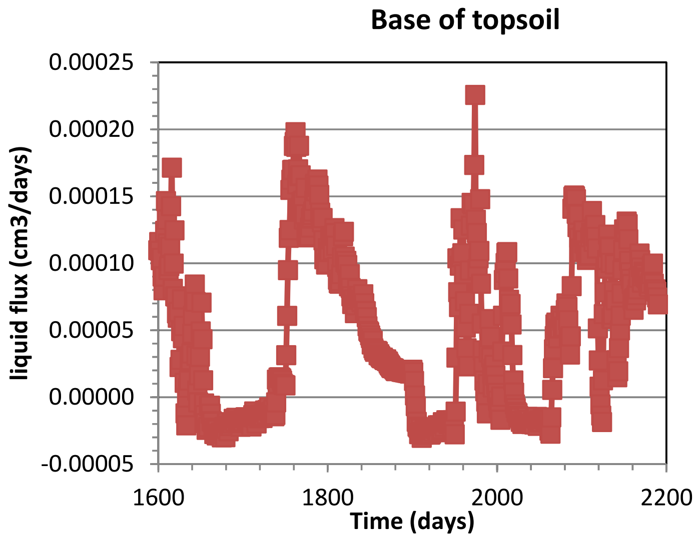


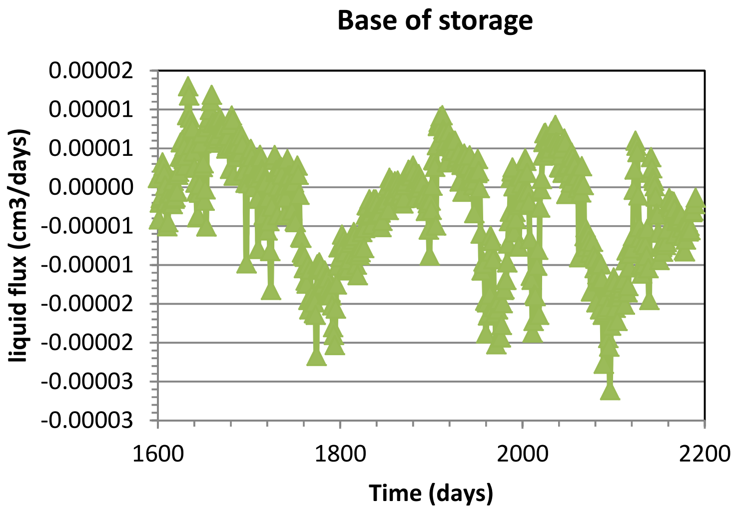

Base of storage
liquid flux (cm3/days)
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
0.000000
1600
1800
2000
2200
Time (days)

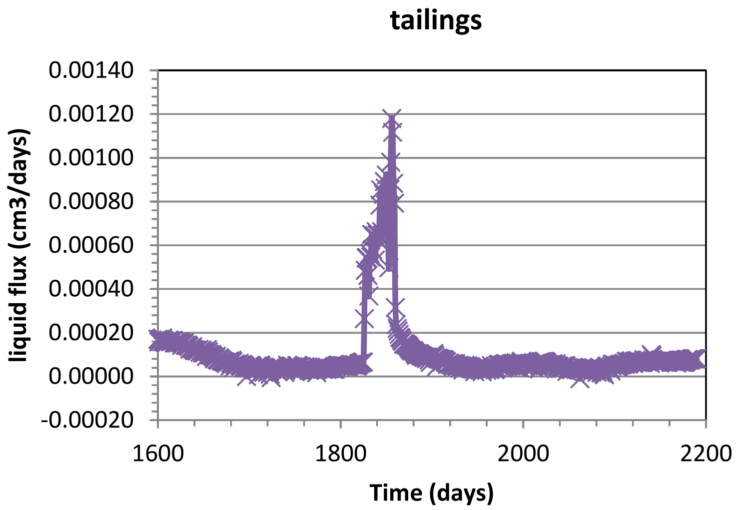

tailings
liquid flux (cm3/days)
0.00010
0.00009
0.00008
0.00007
0.00006
0.00005
0.00004
0.00003
0.00002
0.00001
0.00000
1600
1800
2000
2200
Time (days)

Scenario 11a – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm). Extreme event applied.

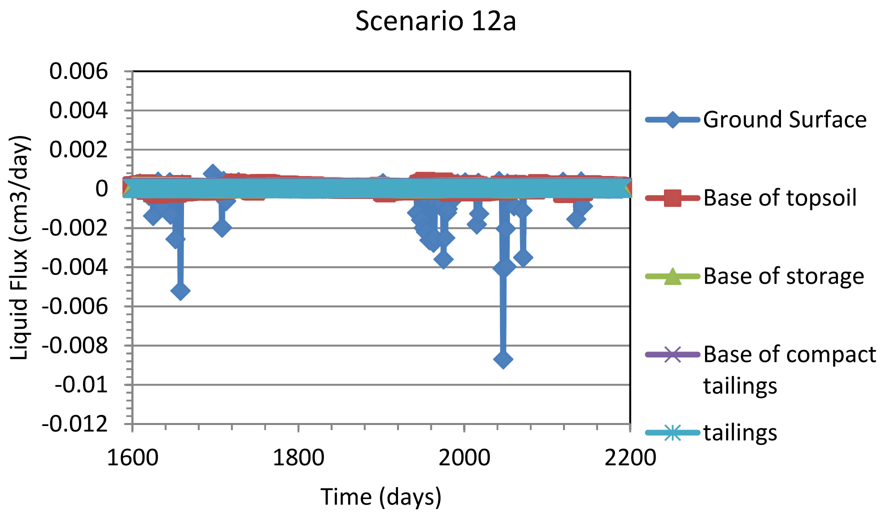


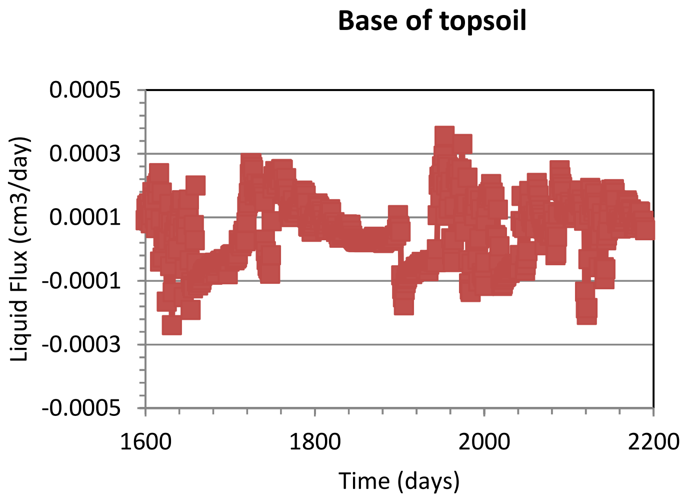


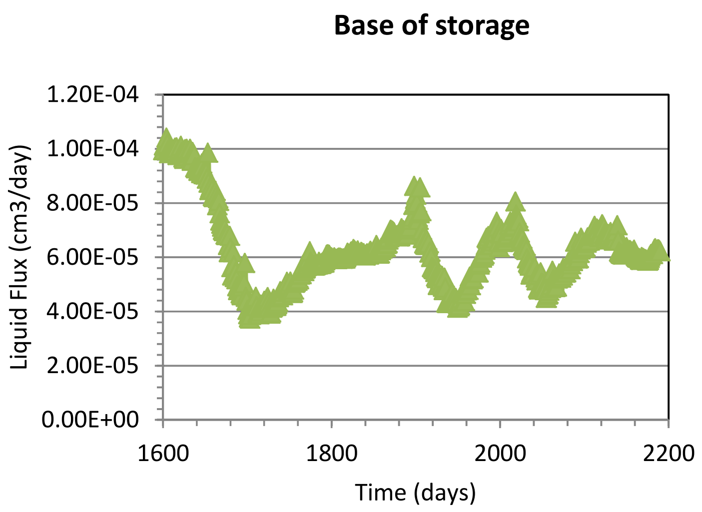

Base of storage
0.00002
0.00001
0.00001
0.00000
-0.00001
-0.00001
-0.00002
-0.00002
-0.00003
-0.00003
liquid flux (cm3/days)
1600
1800
2000
2200
Time (days)

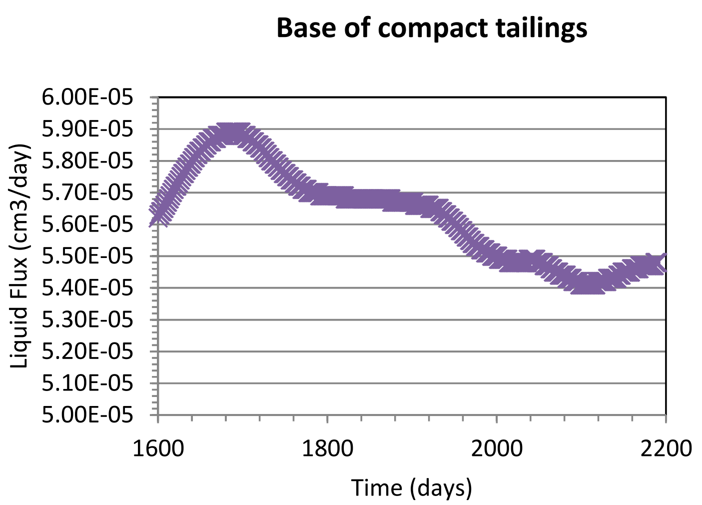

tailings
0.00140
0.00120
0.00100
0.00080
0.00060
0.00040
0.00020
0.00000
-0.00020
liquid flux (cm3/days)
1600
1800
2000
2200
Time (days)

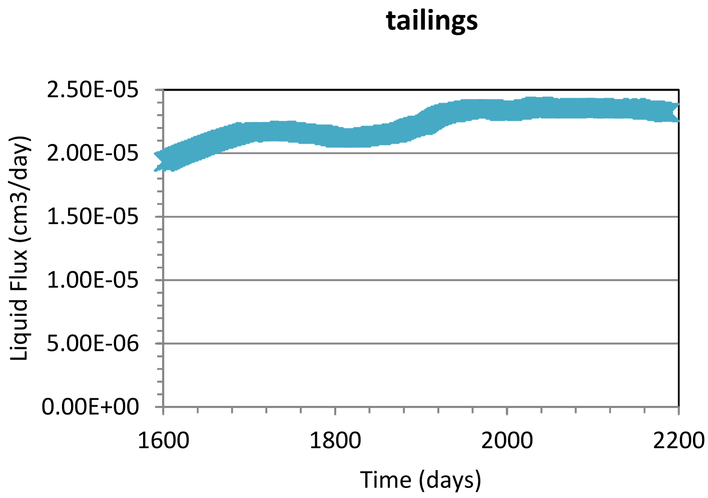
Scenario 12a – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m). Extreme event applied.



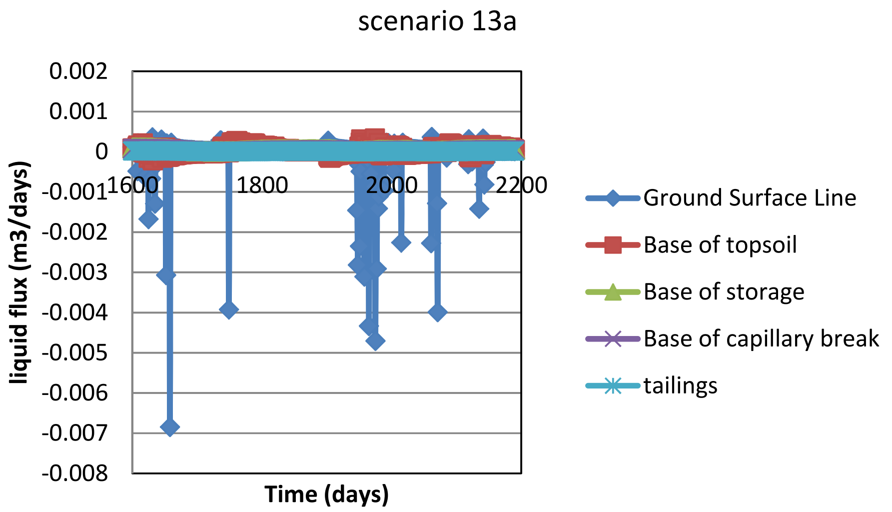


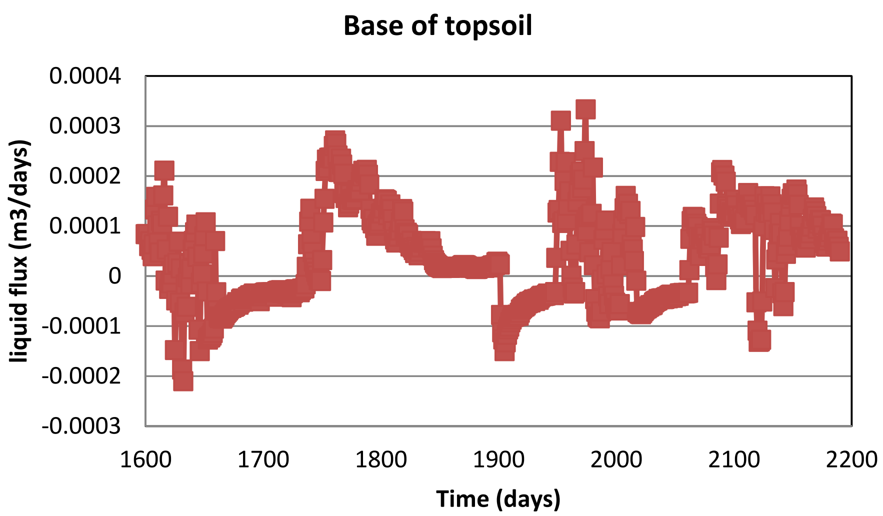

Base of storage
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
Liquid Flux (cm3/day)
1600
1800
2000
2200
Time (days)

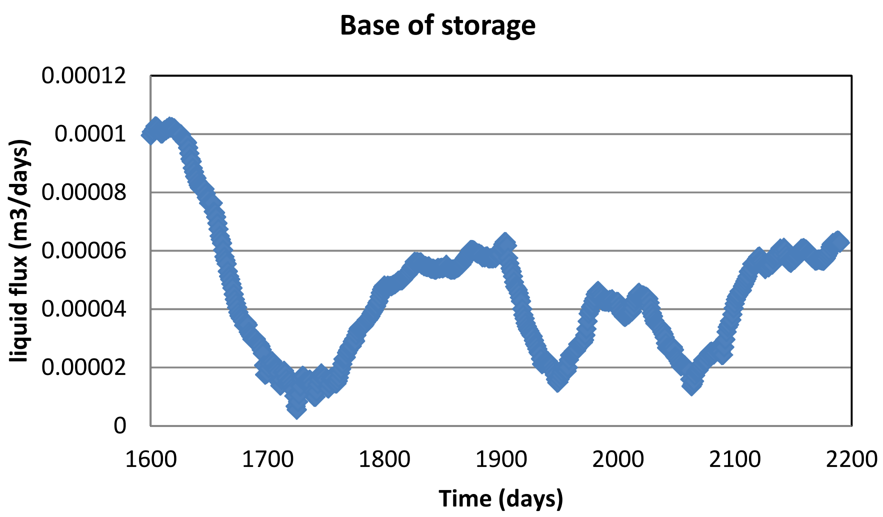

Base of compact tailings
6.00E-05
5.90E-05
5.80E-05
5.70E-05
5.60E-05
5.50E-05
5.40E-05
5.30E-05
5.20E-05
5.10E-05
5.00E-05
Liquid Flux (cm3/day)
1600
1800
2000
2200
Time (days)

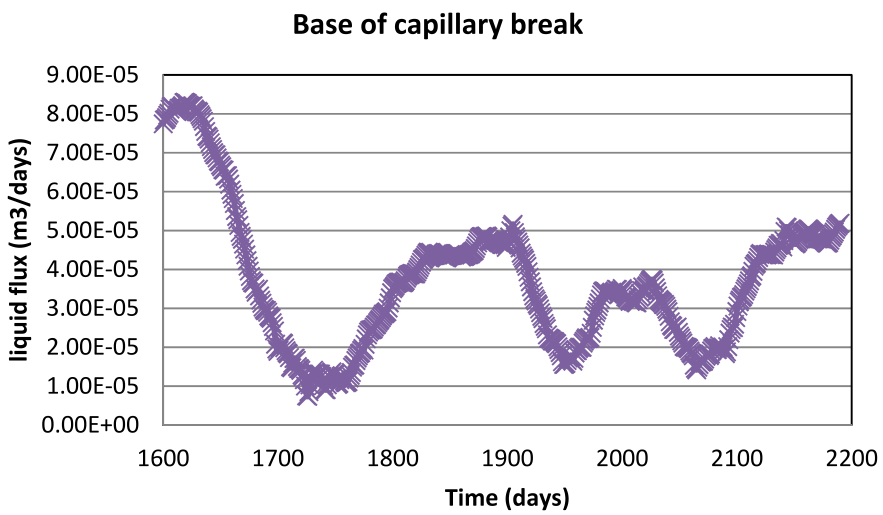

tailings
Liquid Flux (cm3/day)
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1600
1800
2000
2200
Time (days)

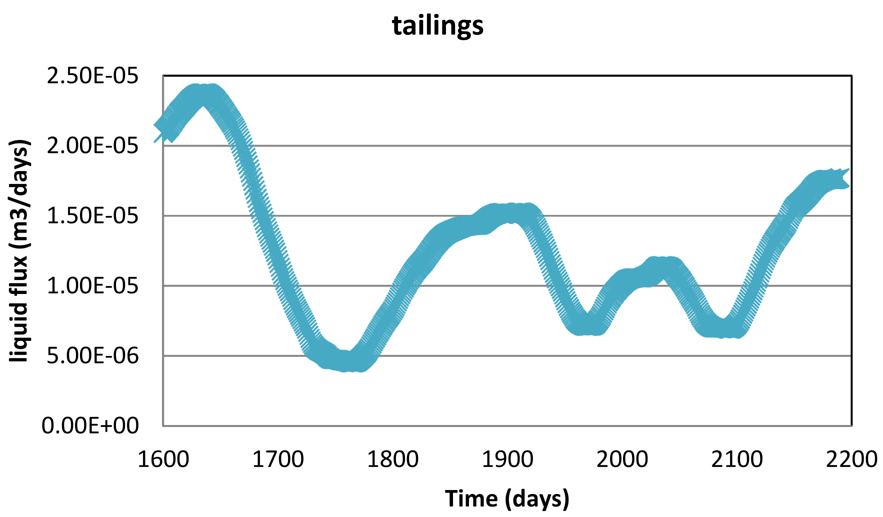
Scenario 13a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m). Extreme event applied.



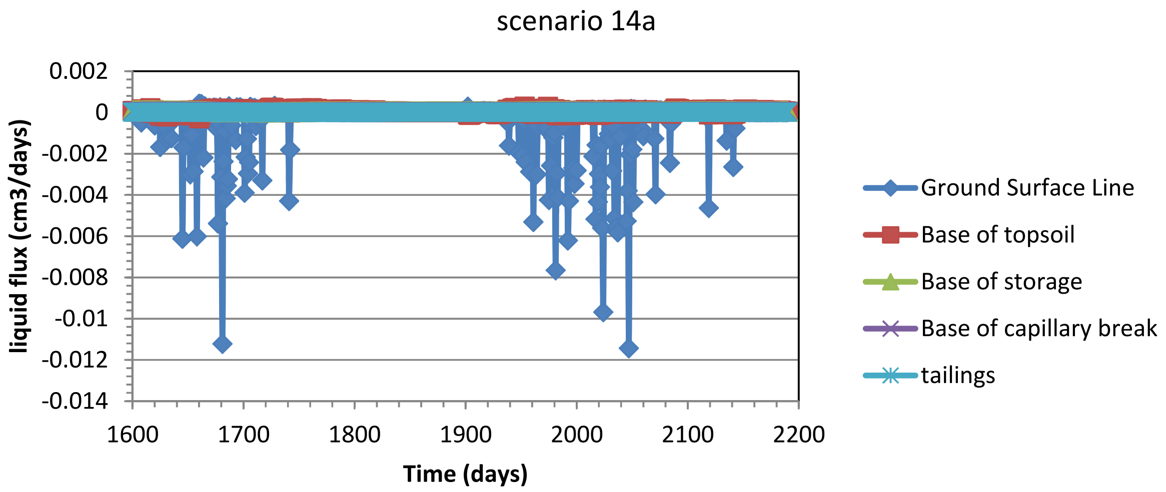


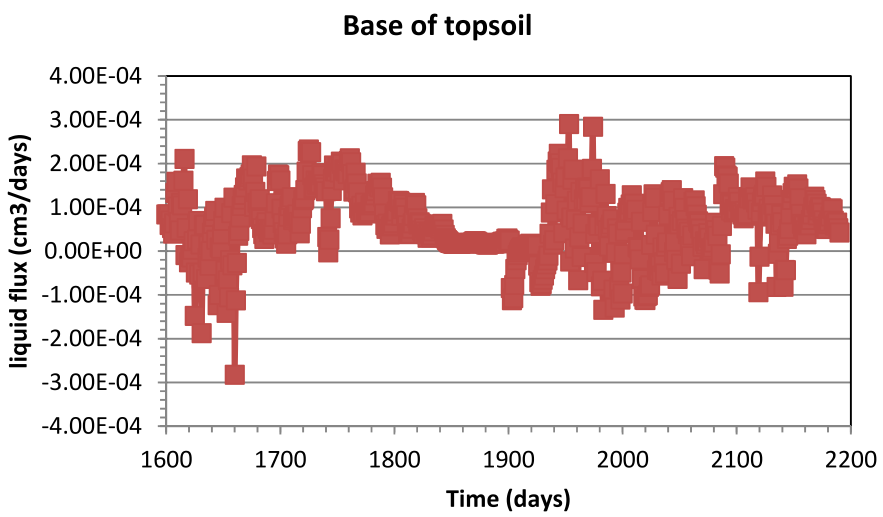

Base of storage
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

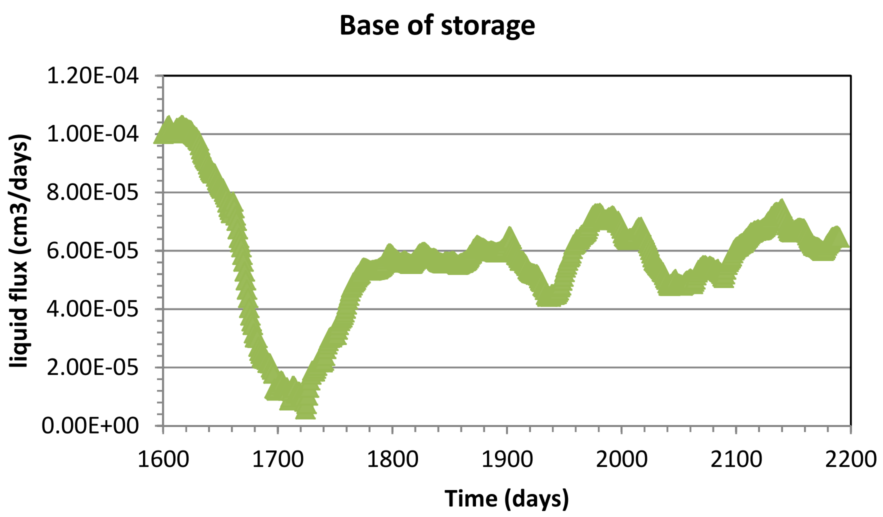

Base of capillary break
9.00E-05
8.00E-05
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

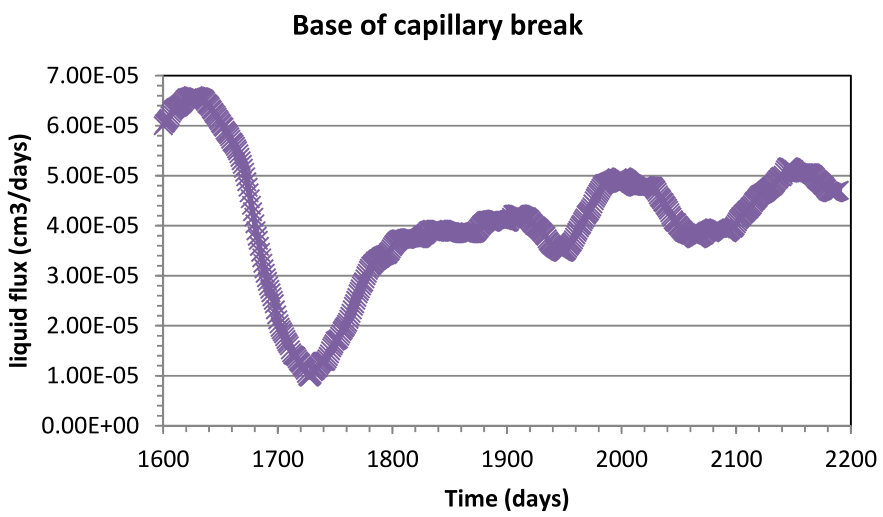

tailings
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
liquid flux (m3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

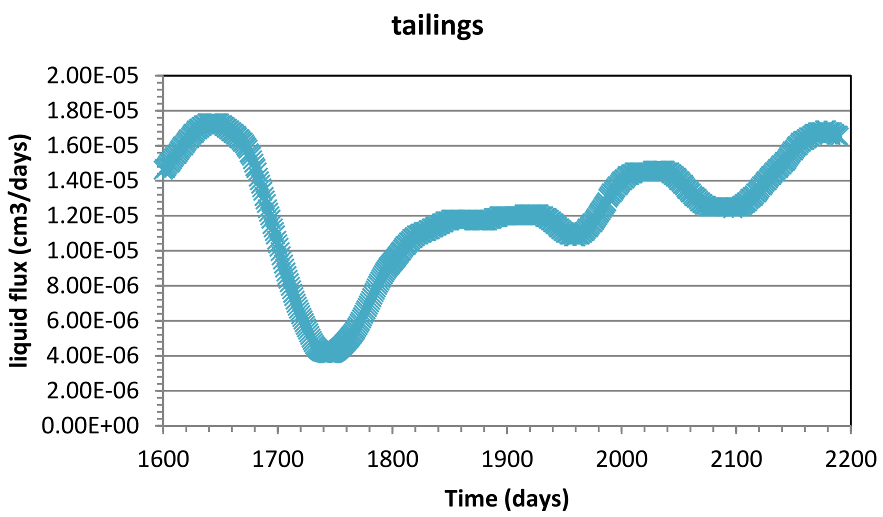
Scenario 14a – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m). Extreme event applied.



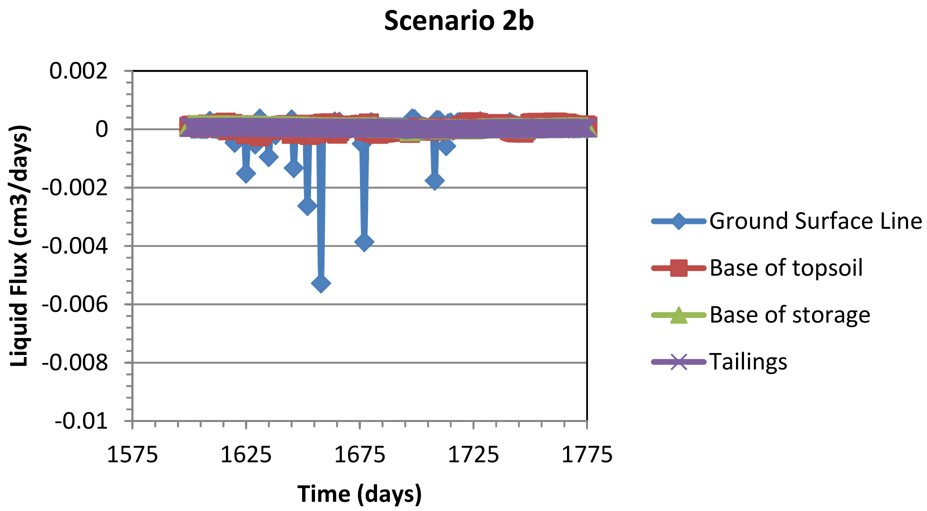


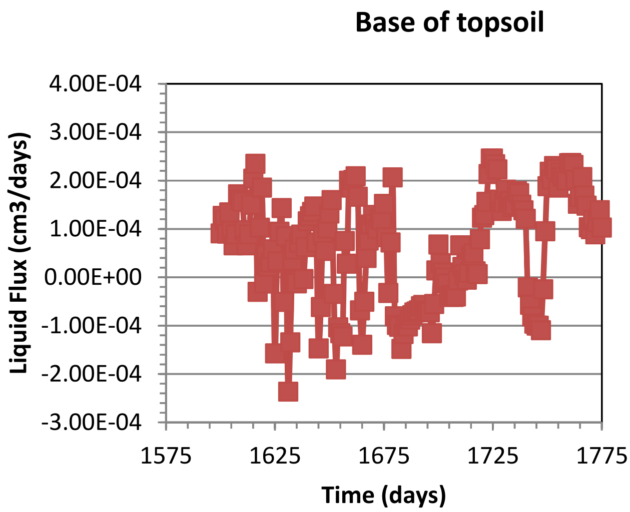

Base of storage
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
liquid flux (cm3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

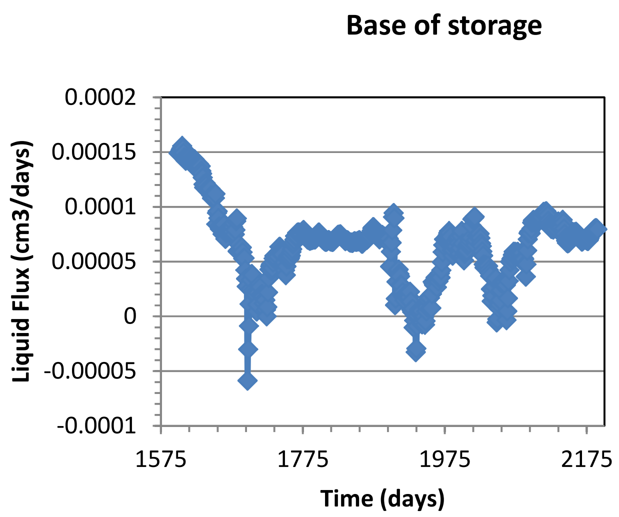

Base of capillary break
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
liquid flux (cm3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

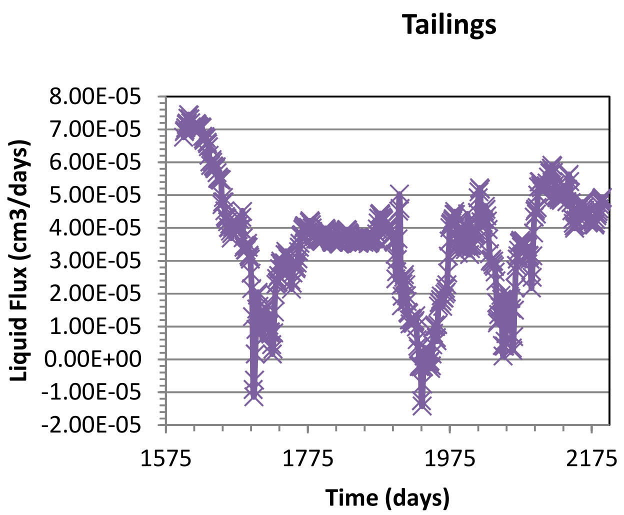

tailings
2.00E-05
1.80E-05
1.60E-05
1.40E-05
1.20E-05
1.00E-05
8.00E-06
6.00E-06
4.00E-06
2.00E-06
0.00E+00
liquid flux (cm3/days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

Scenario 2b – Type 1: vegetation; topsoil (15 cm); storage layer (1 m).

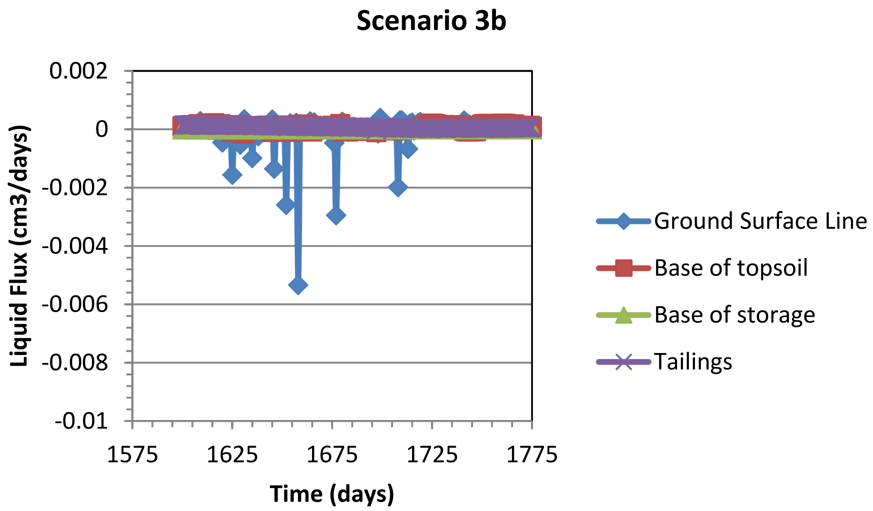


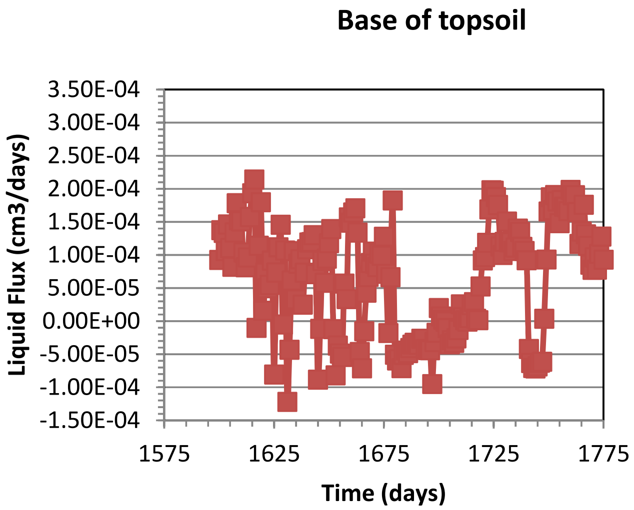


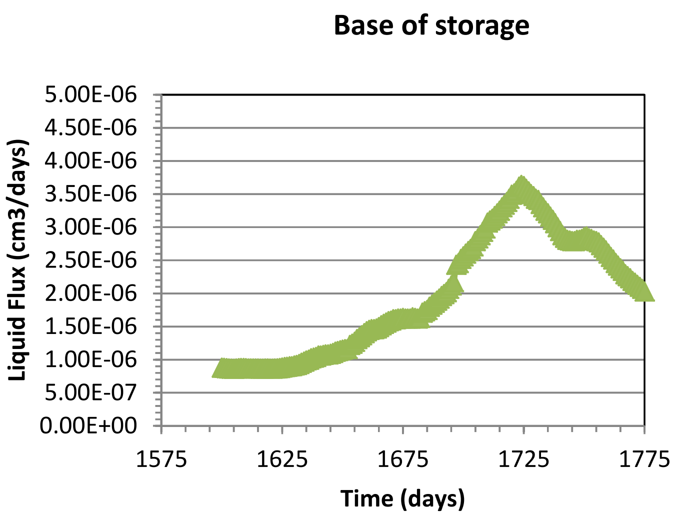

Base of storage
0.0002
0.00015
0.0001
0.00005
0
-0.00005
-0.0001
Liquid Flux (cm3/days)
1575
1775
1975
2175
Time (days)

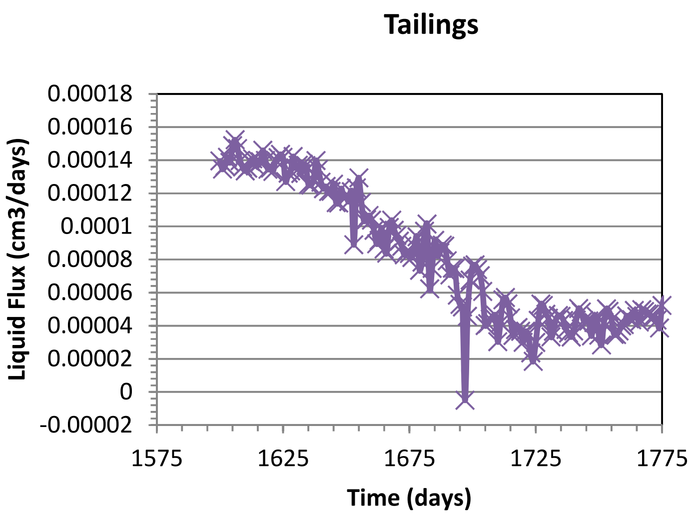

Tailings
8.00E-05
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
-1.00E-05
-2.00E-05
Liquid Flux (cm3/days)
1575
1775
1975
2175
Time (days)

Scenario 3b – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m).

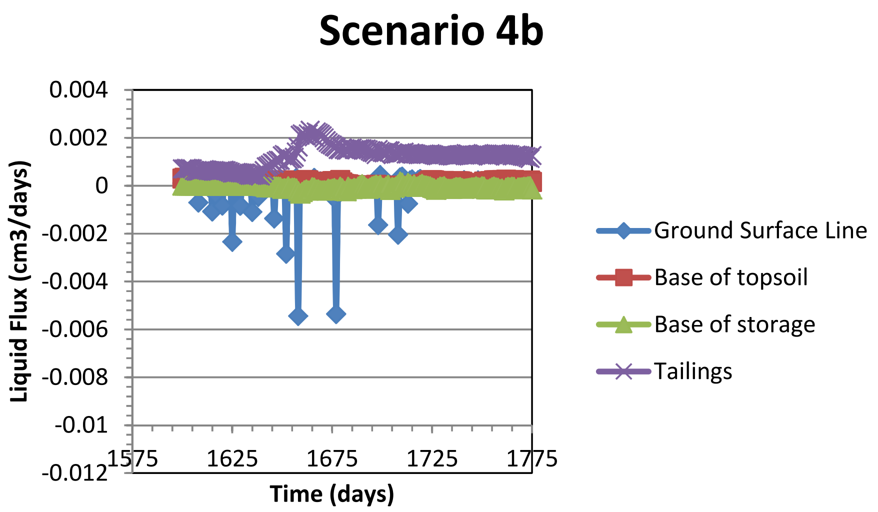


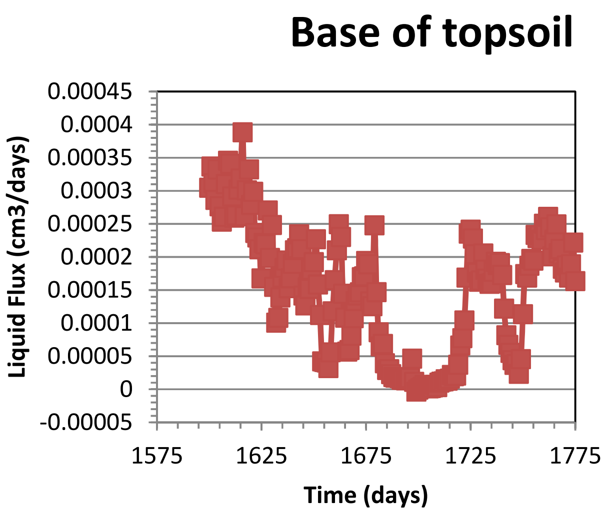


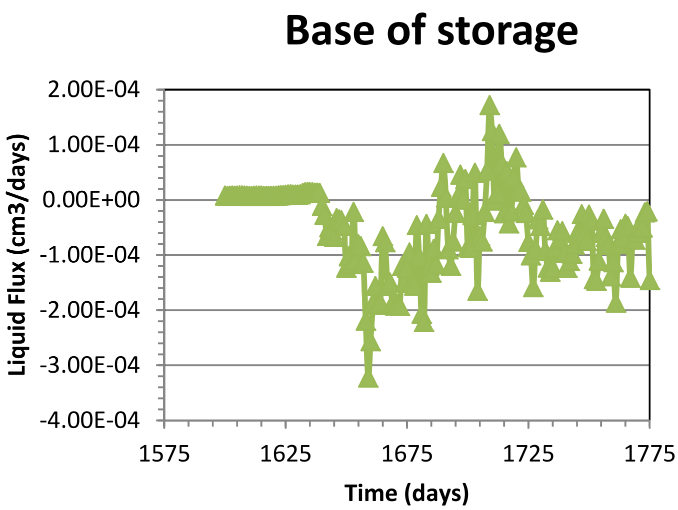

Base of storage
5.00E-06
4.50E-06
4.00E-06
3.50E-06
3.00E-06
2.50E-06
2.00E-06
1.50E-06
1.00E-06
5.00E-07
0.00E+00
Liquid Flux (cm3/days)
1575
1625
1675
1725
1775
Time (days)

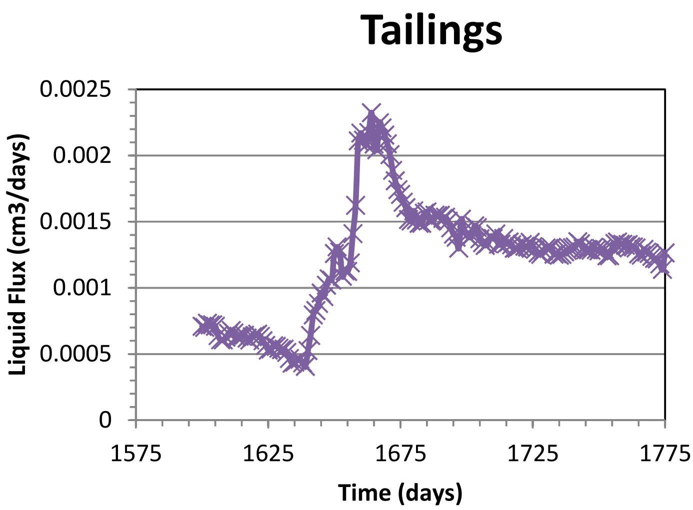

Tailings
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
-0.00002
Liquid Flux (cm3/days)
1575
1625
1675
1725
1775
Time (days)

Scenario 4b – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm).

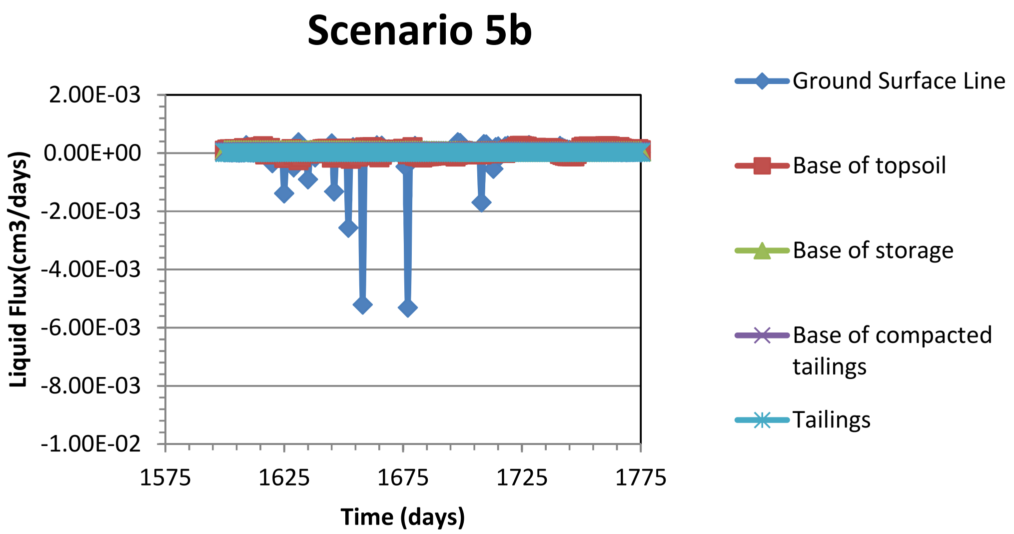


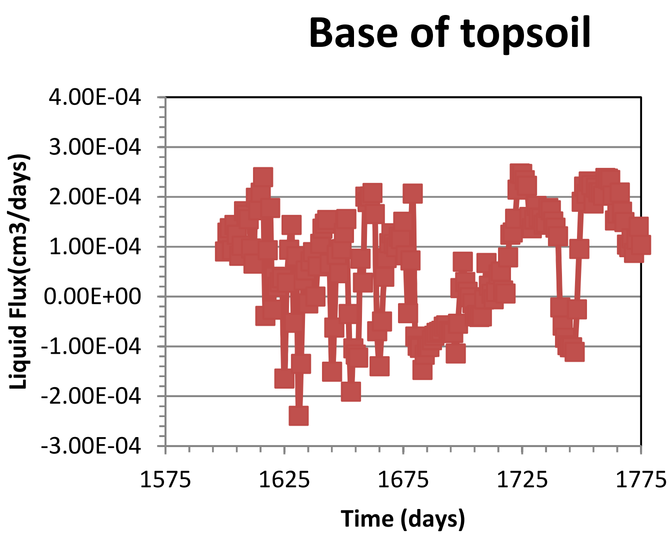


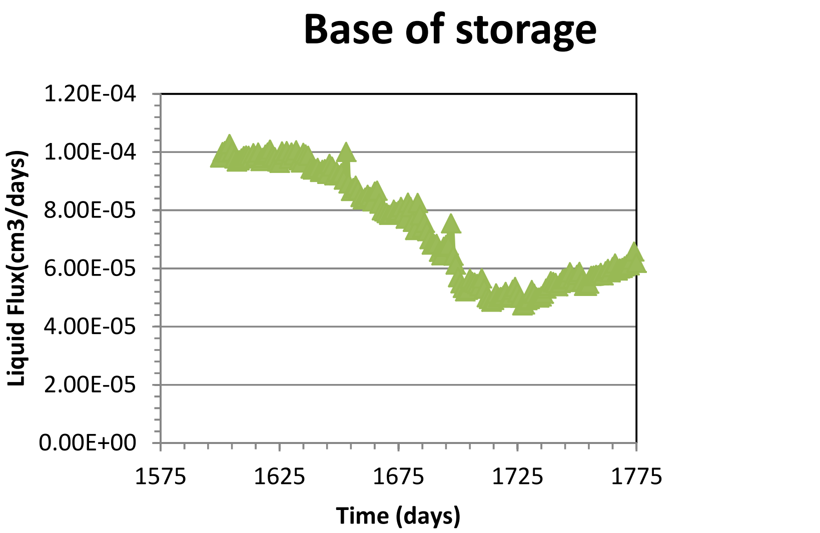

Base of storage
2.00E-04
1.00E-04
0.00E+00
-1.00E-04
-2.00E-04
-3.00E-04
-4.00E-04
Liquid Flux (cm3/days)
1575
1625
1675
1725
1775
Time (days)

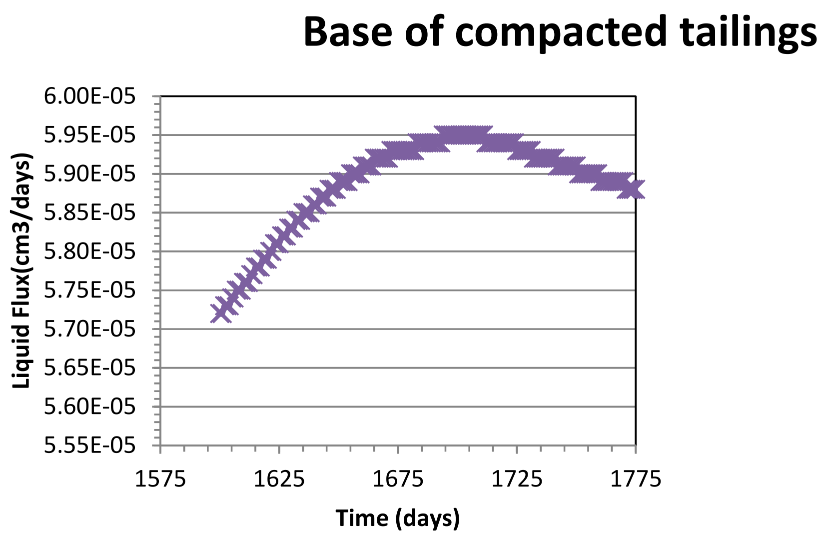

Tailings
0.0025
0.002
0.0015
0.001
0.0005
0
Liquid Flux (cm3/days)
1575
1625
1675
1725
1775
Time (days)

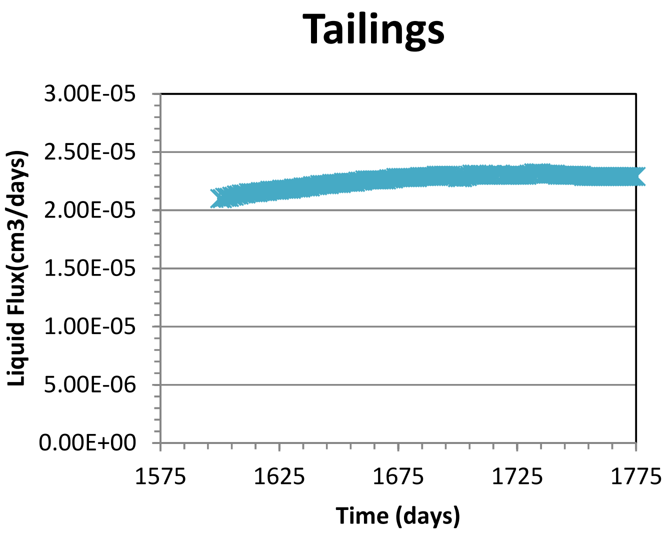
Scenario 5b – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m).



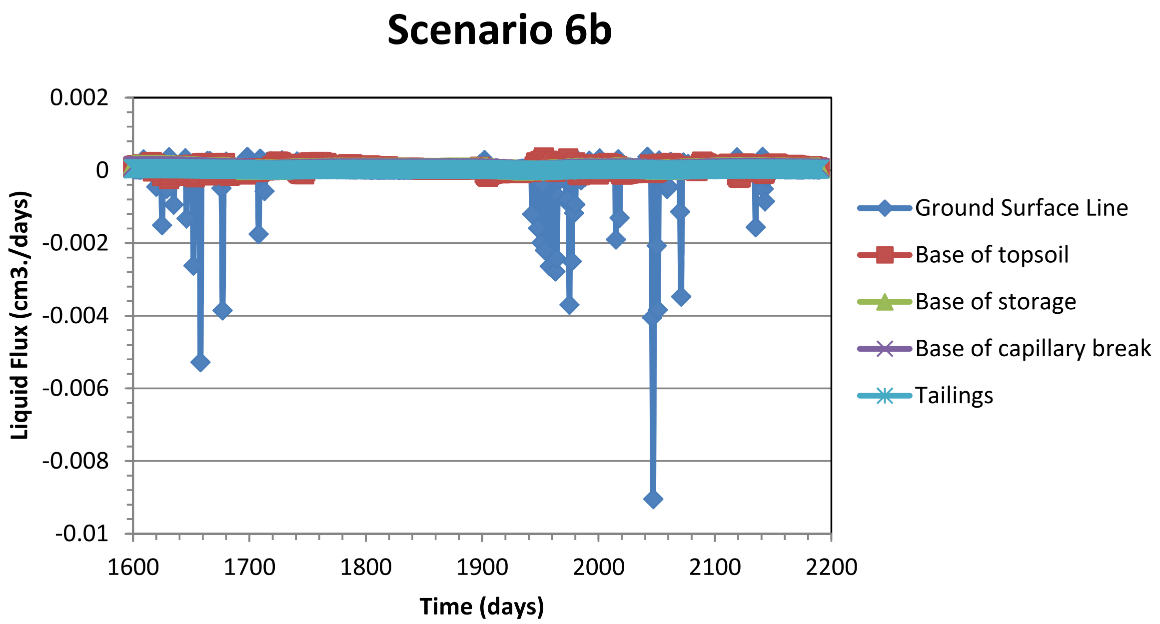


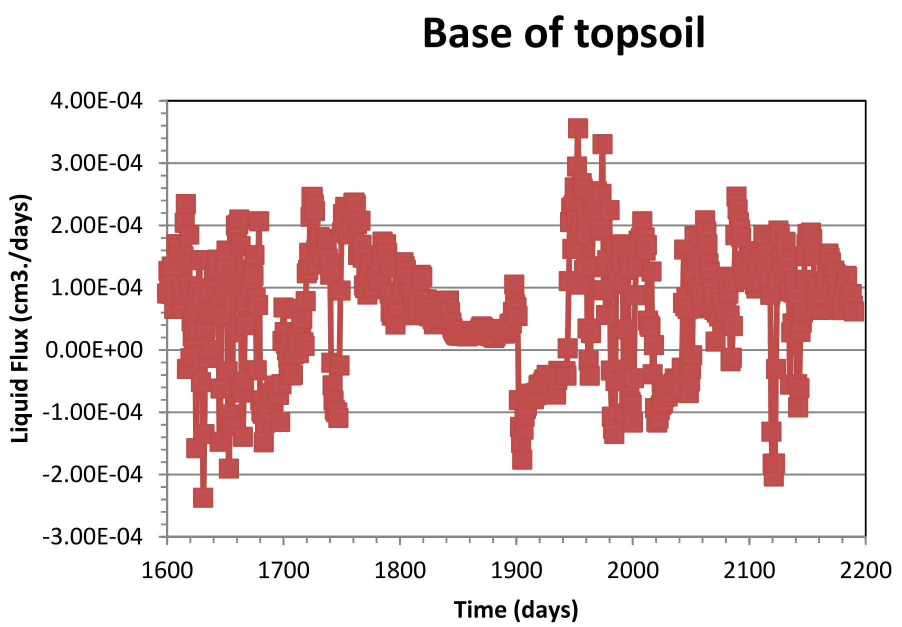

Base of storage
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
Liquid Flux(cm3/days)
1575
1625
1675
1725
1775
Time (days)

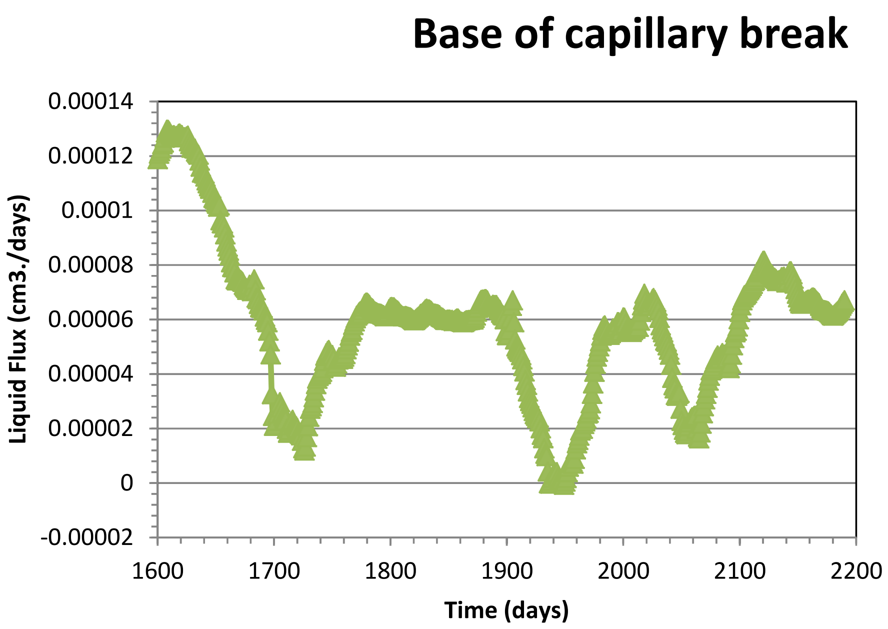

Base of compacted tailings
6.00E-05
5.95E-05
5.90E-05
5.85E-05
5.80E-05
5.75E-05
5.70E-05
5.65E-05
5.60E-05
5.55E-05
Liquid Flux(cm3/days)
1575
1625
1675
1725
1775
Time (days)

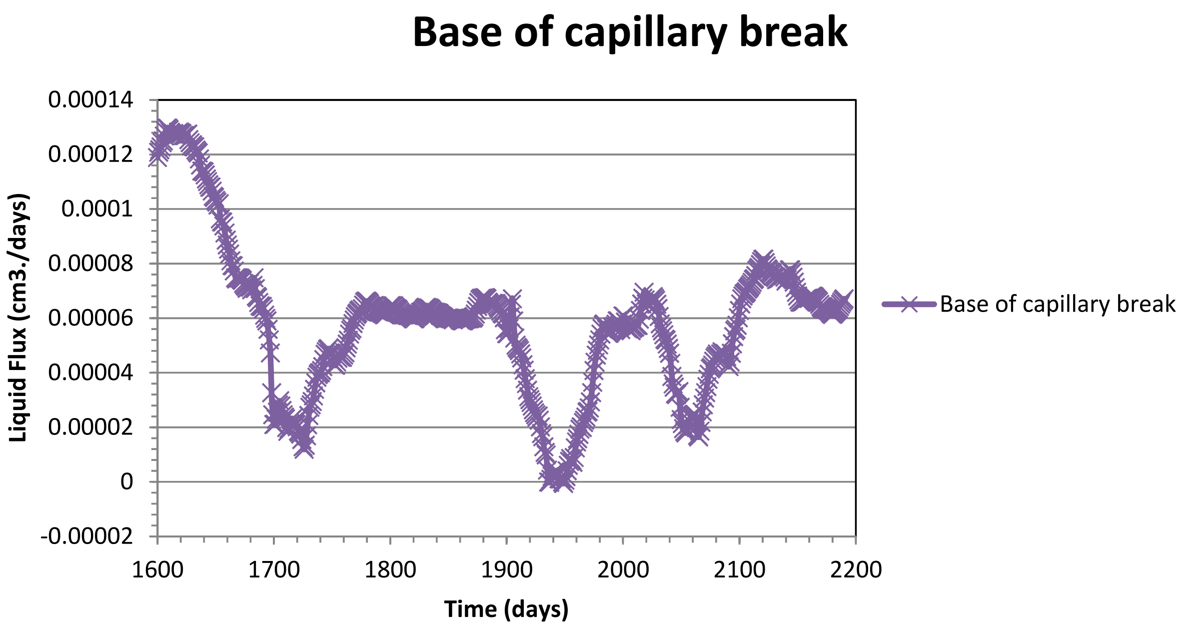

Tailings
Liquid Flux(cm3/days)
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1575
1625
1675
1725
1775
Time (days)

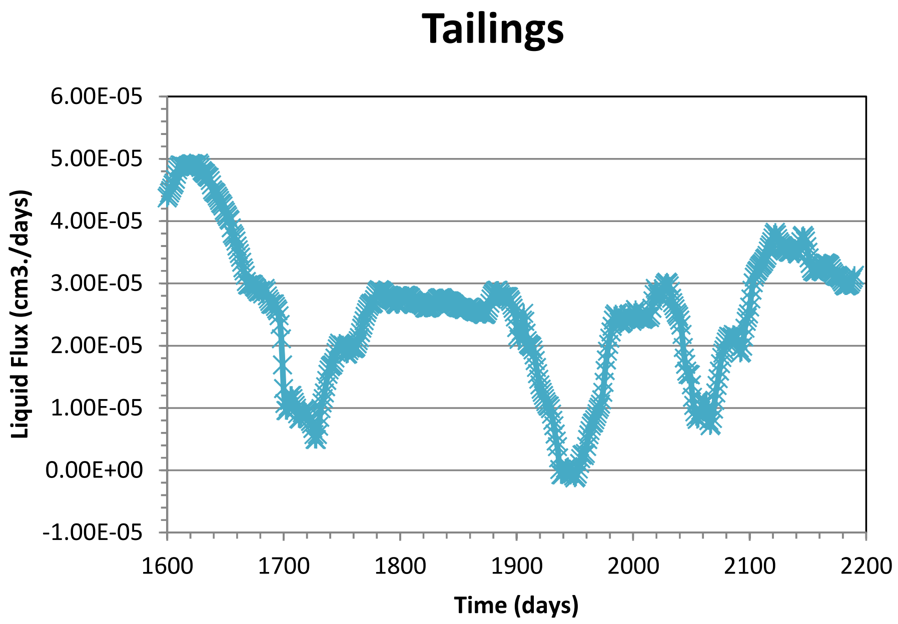
Scenario 6b – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m)



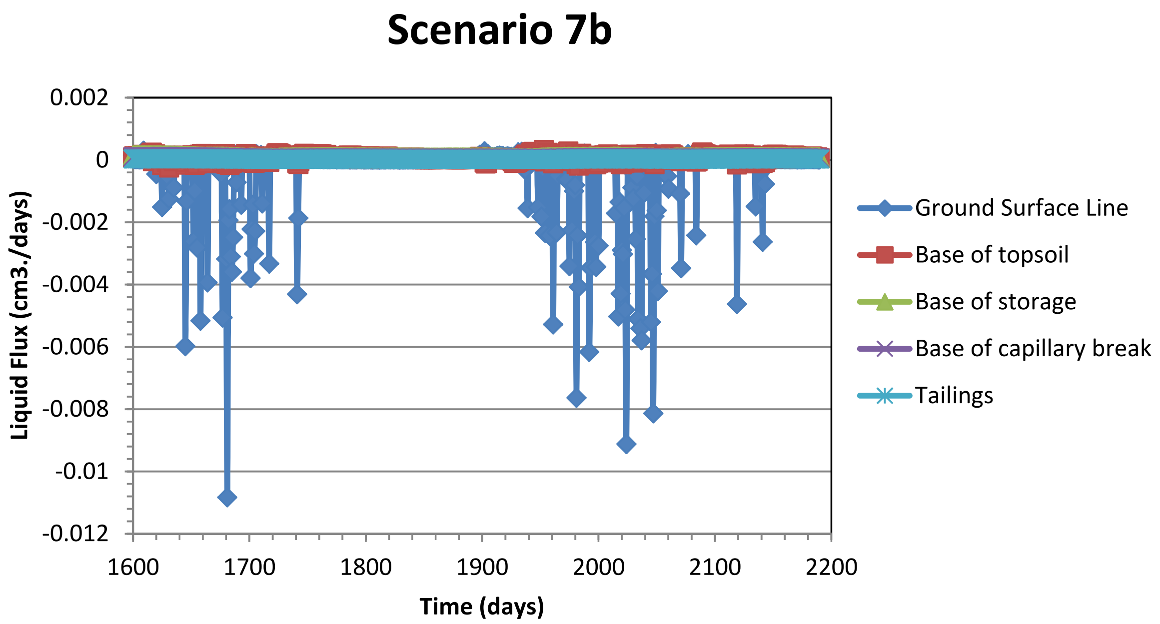


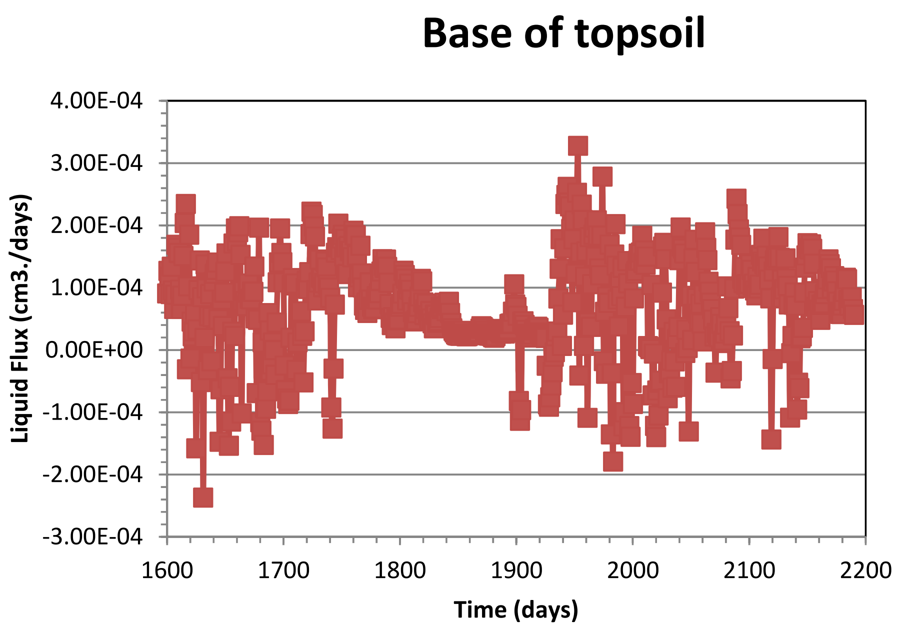

Base of capillary break
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
-0.00002
Liquid Flux (cm3./days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

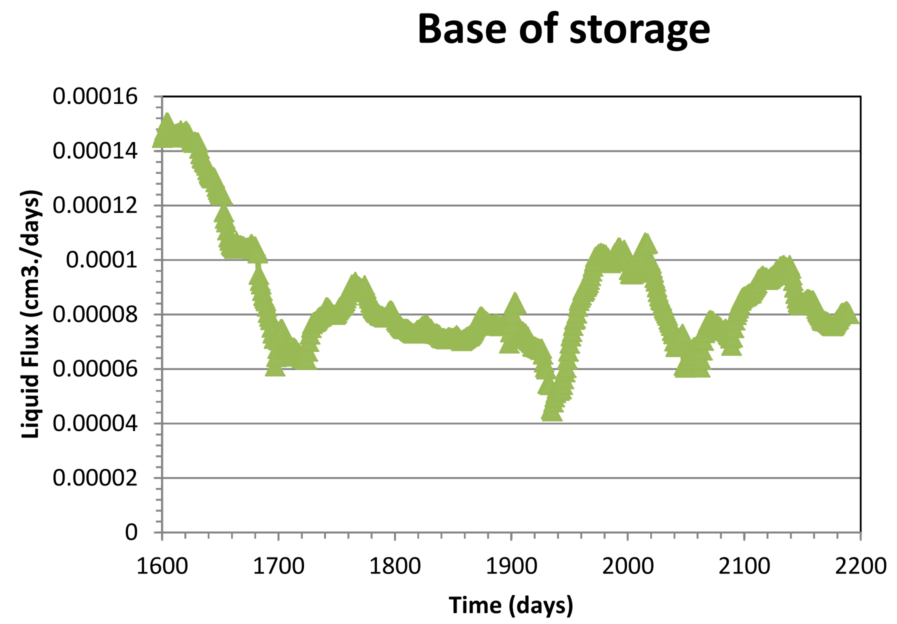

Base of capillary break
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
-0.00002
Liquid Flux (cm3./days)
1600
1700
1800
1900
2000
2100
2200
Time (days)
Base of capillary break

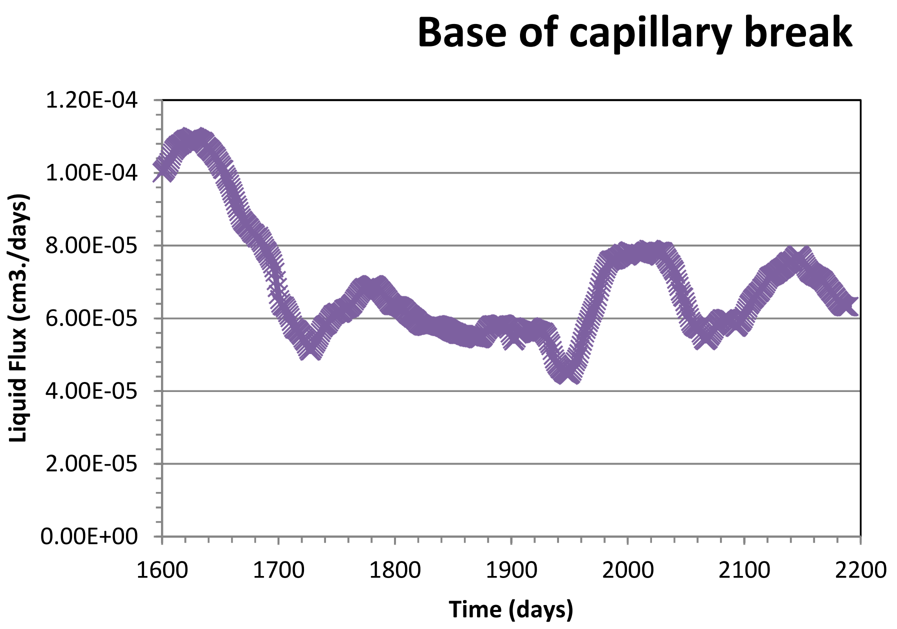

Tailings
Liquid Flux (cm3./days)
Time (days)
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
-1.00E-05
1600
1700
1800
1900
2000
2100
2200

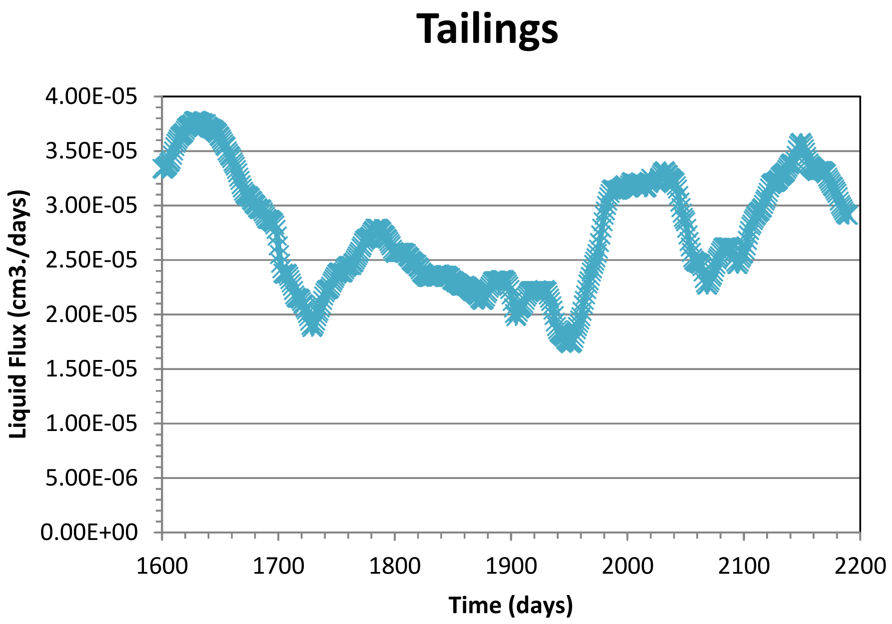
Scenario 7b – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m)



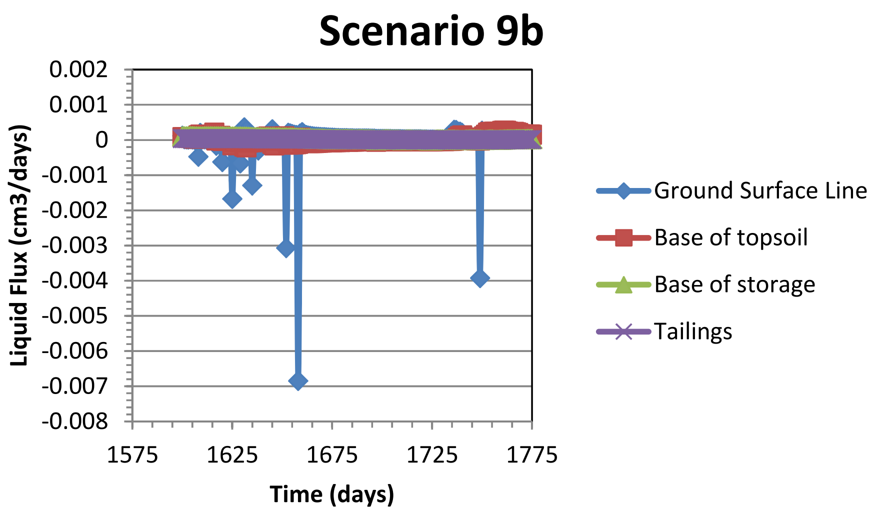


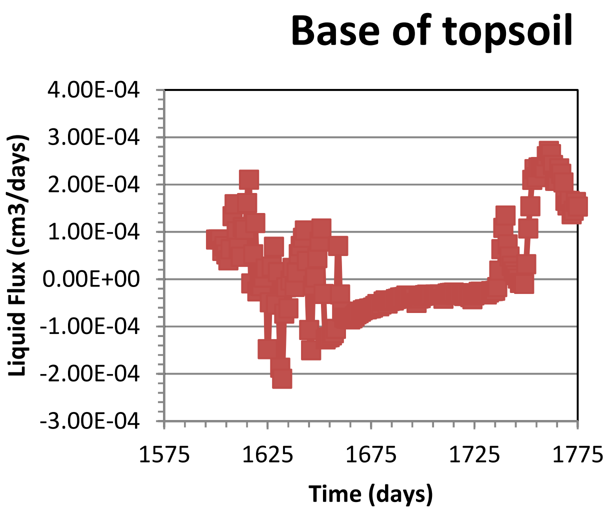

Base of storage
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
Liquid Flux (cm3./days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

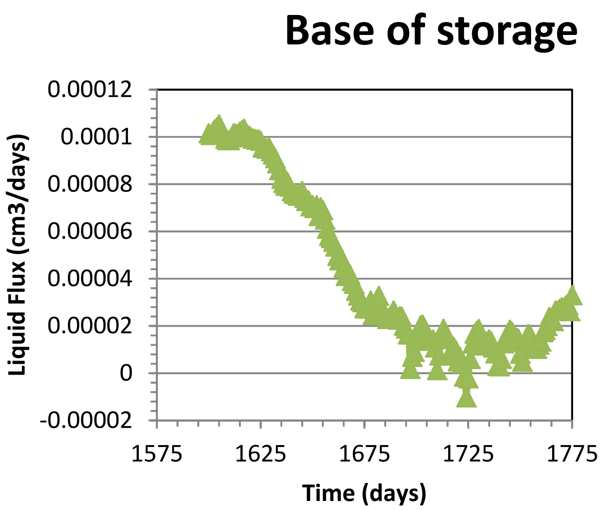

Base of capillary break
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
Liquid Flux (cm3./days)
1600
1700
1800
1900
2000
2100
2200
Time (days)

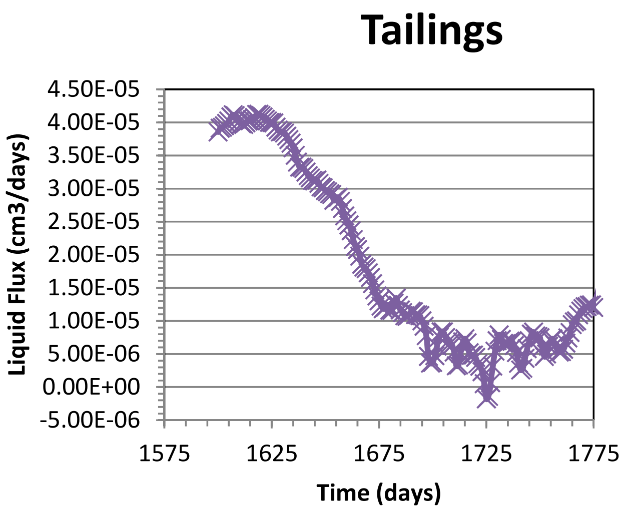

Tailings
Liquid Flux (cm3./days)
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1600
1700
1800
1900
2000
2100
2200
Time (days)

Scenario 9b – Type 1: vegetation; topsoil (15 cm); storage layer (1 m). Extreme event applied.

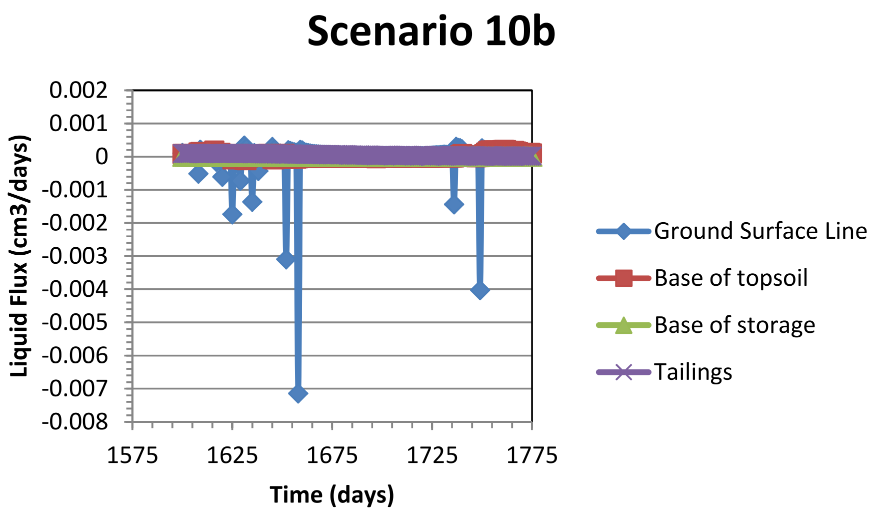


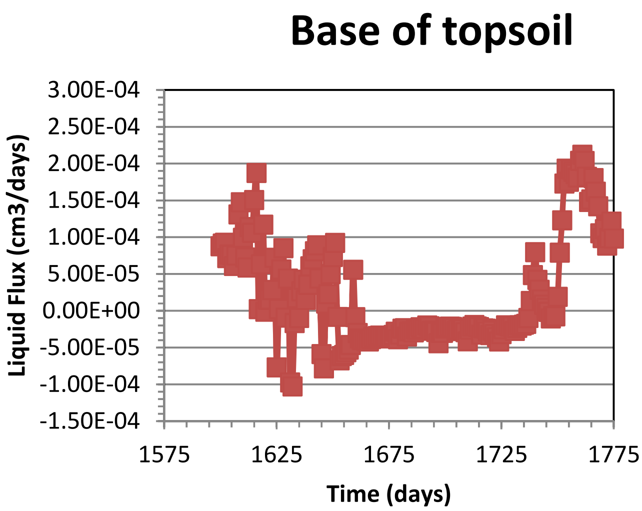


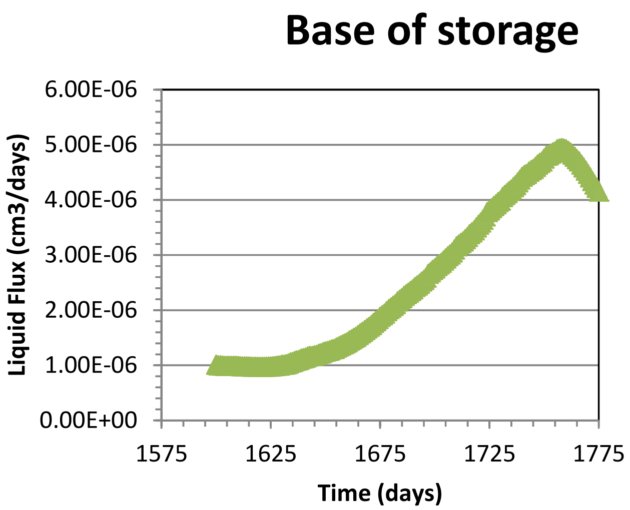

Base of storage
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
-0.00002
Liquid Flux (cm3/days)
1575
1625
1675
1725
1775
Time (days)

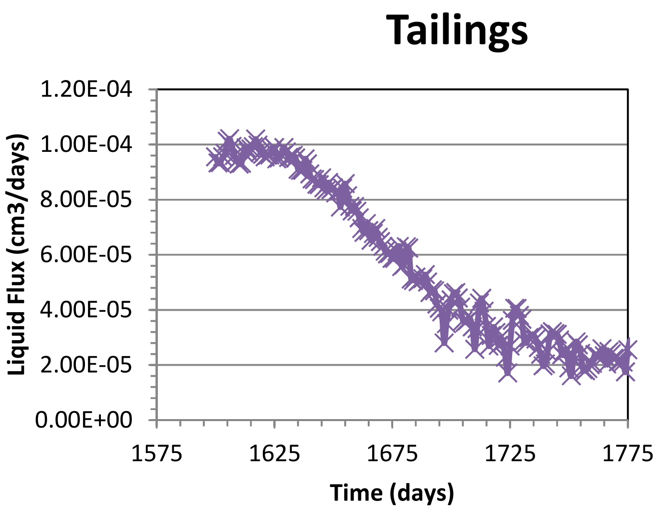

Tailings
4.50E-05
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
-5.00E-06
Liquid Flux (cm3/days)
1575
1625
1675
1725
1775
Time (days)

Scenario 10b – Type 1: vegetation; topsoil (15 cm); storage layer (0.5 m). Extreme event applied.

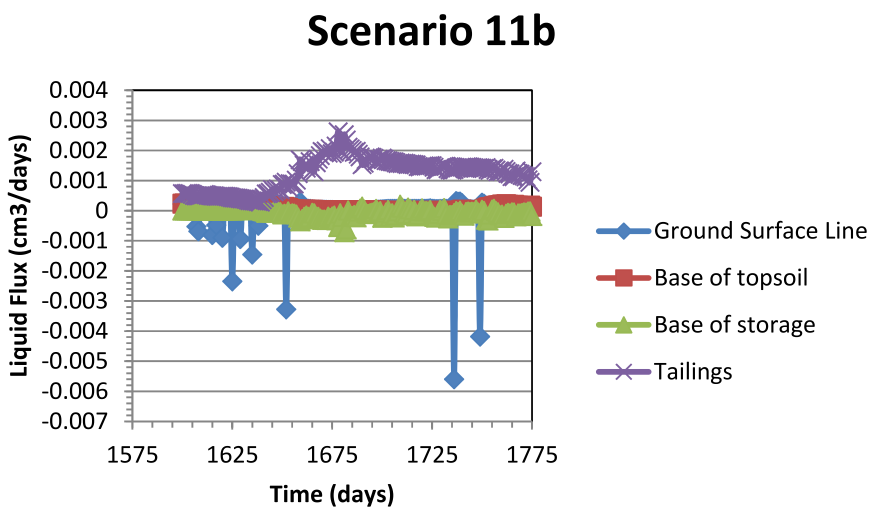


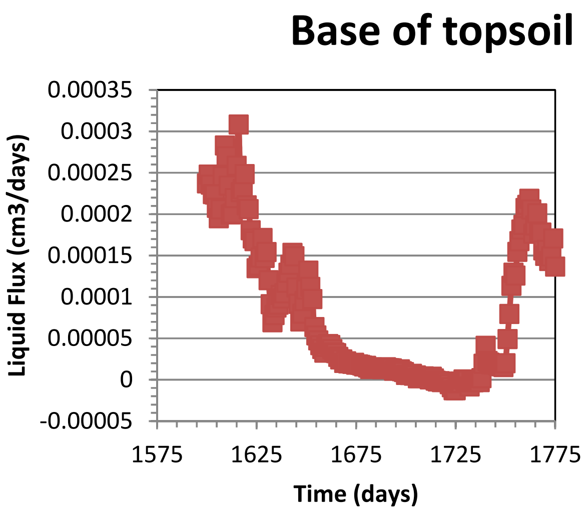


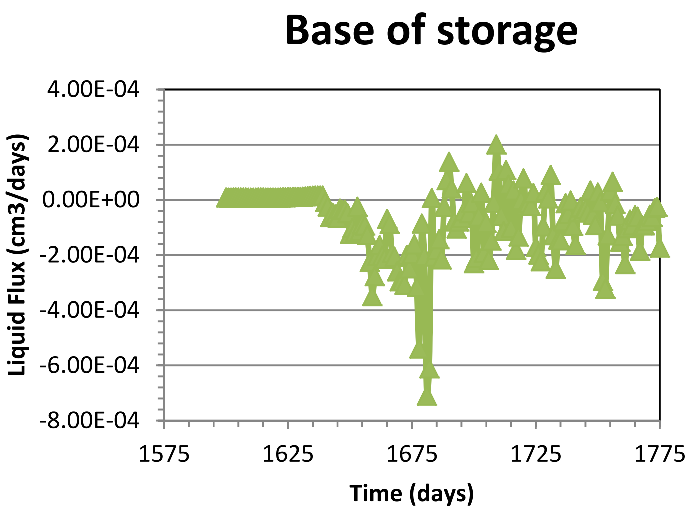

Base of storage
6.00E-06
5.00E-06
4.00E-06
3.00E-06
2.00E-06
1.00E-06
0.00E+00
Liquid Flux (cm3/days)
1575
1625
1675
1725
1775
Time (days)

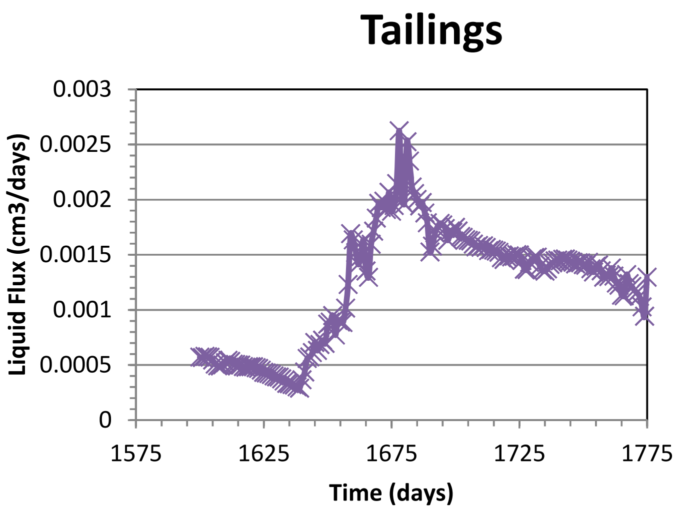

Tailings
1.20E-04
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
Liquid Flux (cm3/days)
1575
1625
1675
1725
1775
Time (days)

Scenario 11b – Type 1: vegetation; topsoil (15 cm); storage layer (10 cm). Extreme event applied.

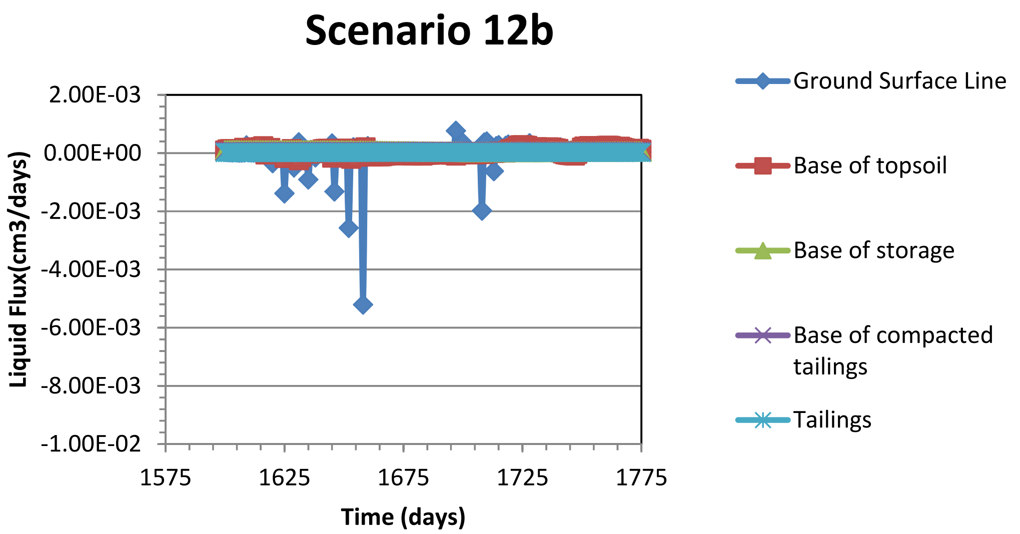


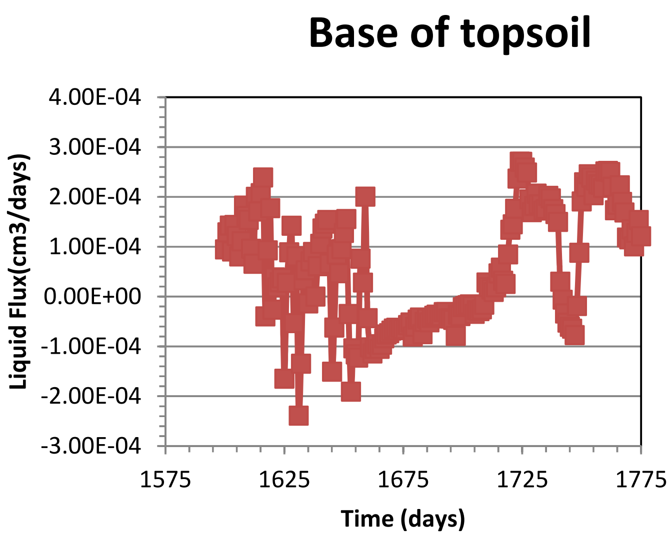



Base of storage
Liquid Flux (cm3/days)
4.00E-04
2.00E-04
0.00E+00
-2.00E-04
-4.00E-04
-6.00E-04
-8.00E-04
1575
1625
1675
1725
1775
Time (days)

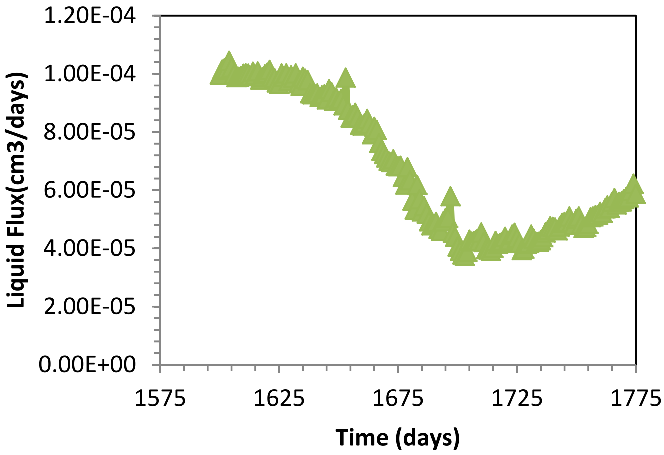

Tailings
Liquid Flux (cm3/days)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
1575
1625
1675
1725
1775
Time (days)

Scenario 12b – Type 2: vegetation; topsoil (15 cm); storage layer (1 m); compacted tailings layer (0.5m). Extreme event applied.

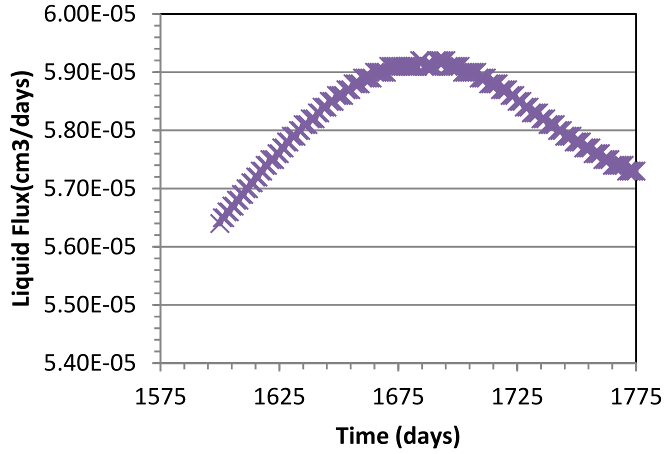


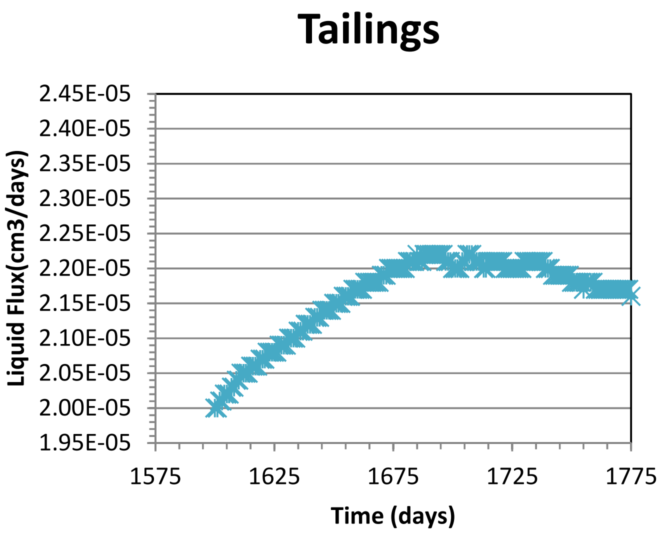


Base of storage

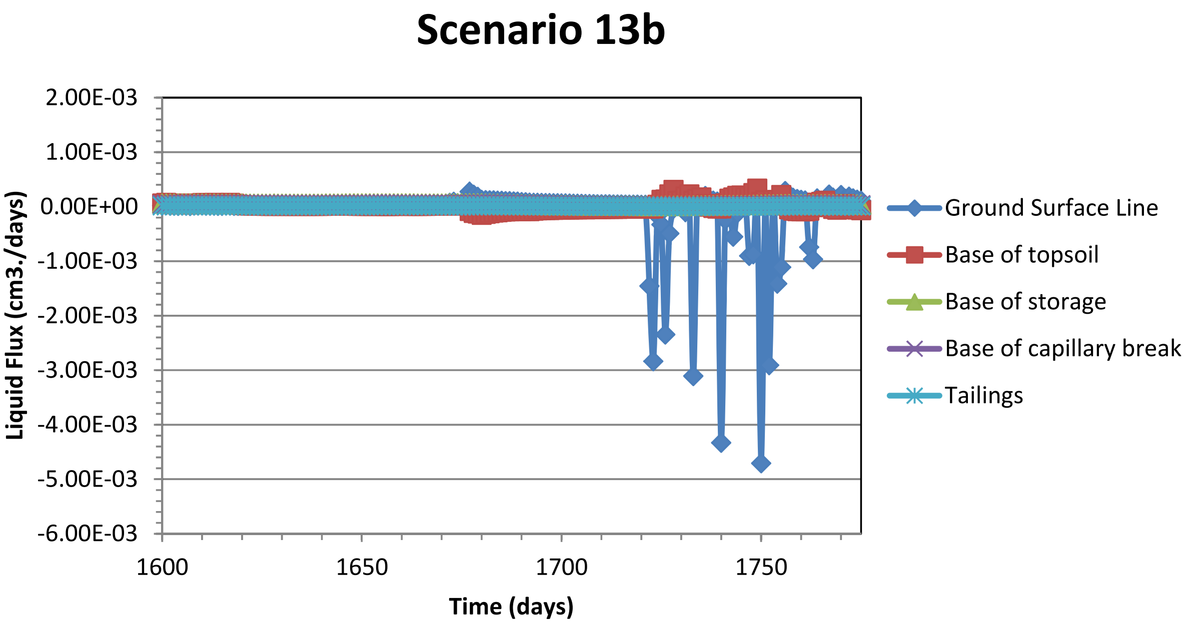


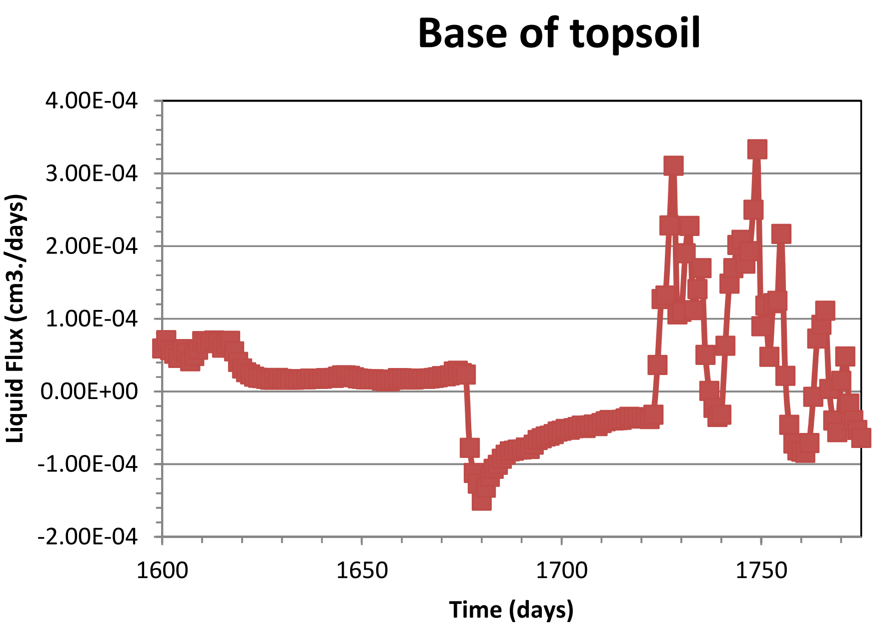
Base of compacted tailings

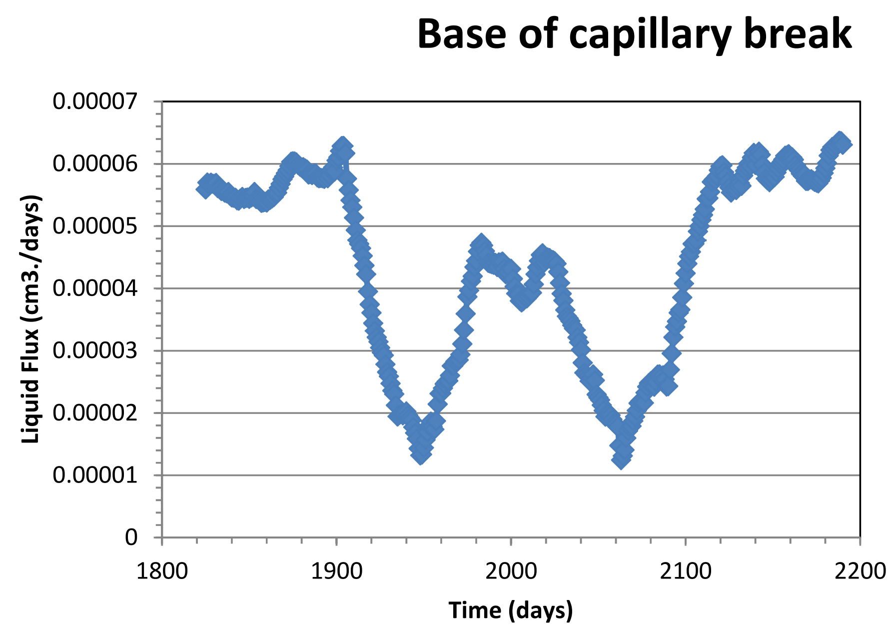


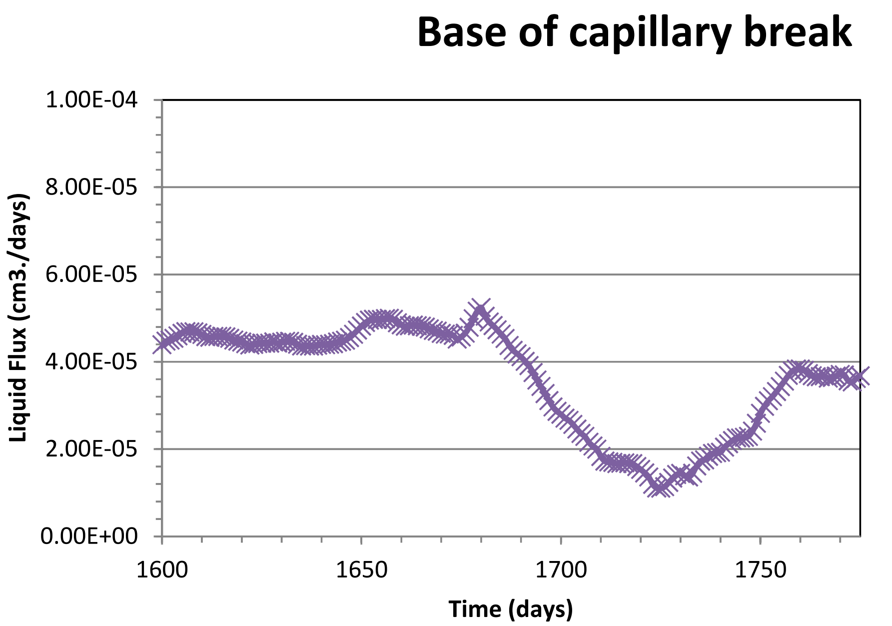

Tailings
Liquid Flux(cm3/days)
2.45E-05
2.40E-05
2.35E-05
2.30E-05
2.25E-05
2.20E-05
2.15E-05
2.10E-05
2.05E-05
2.00E-05
1.95E-05
1575
1625
1675
1725
1775
Time (days)

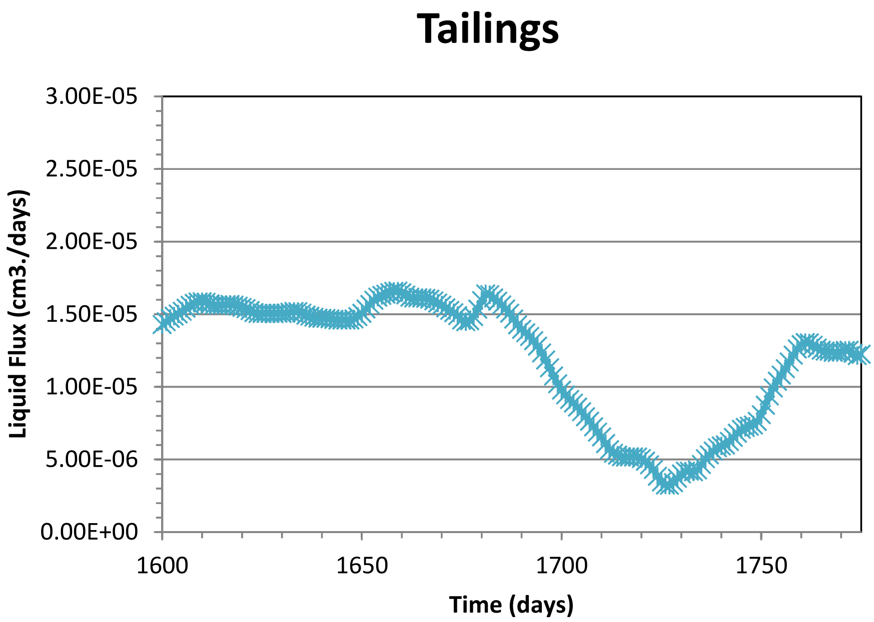
Scenario 13b – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (0.5 m). Extreme event applied.



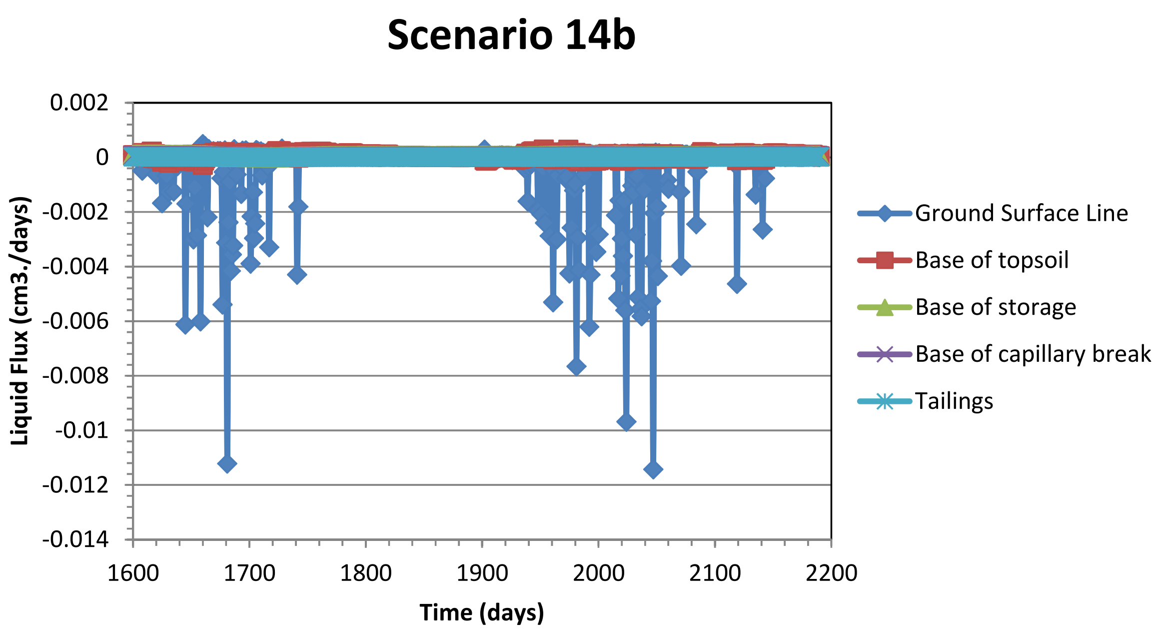


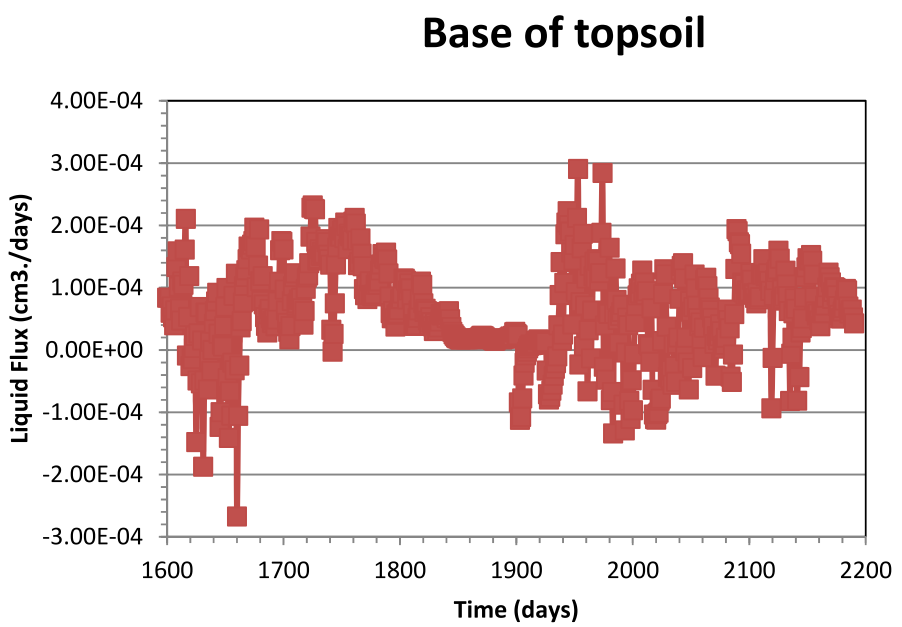

Base of capillary break
0.00007
0.00006
0.00005
0.00004
0.00003
0.00002
0.00001
0
Liquid Flux (cm3./days)
1800
1900
2000
2100
2200
Time (days)

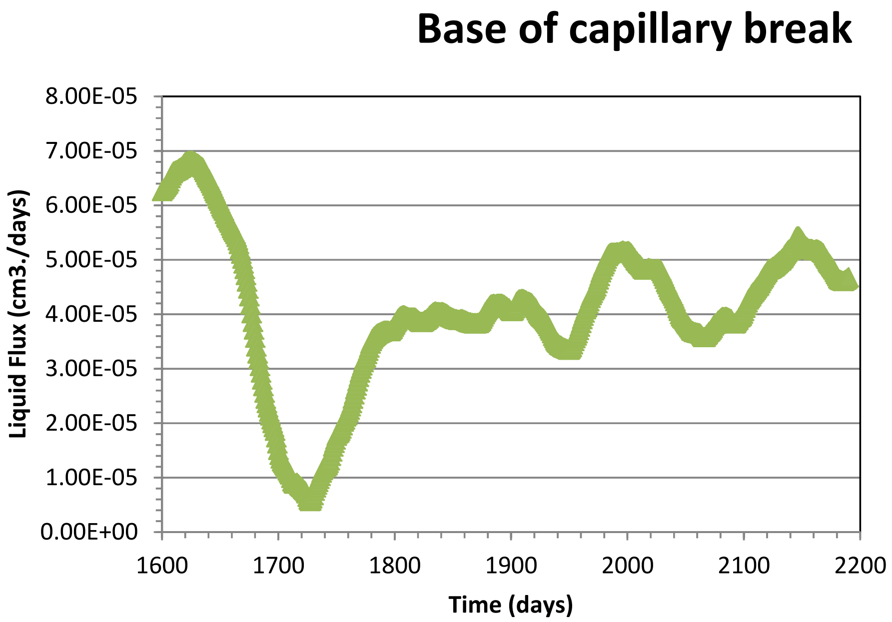

Base of capillary break
1.00E-04
8.00E-05
6.00E-05
4.00E-05
2.00E-05
0.00E+00
Liquid Flux (cm3./days)
1600
1650
1700
1750
Time (days)

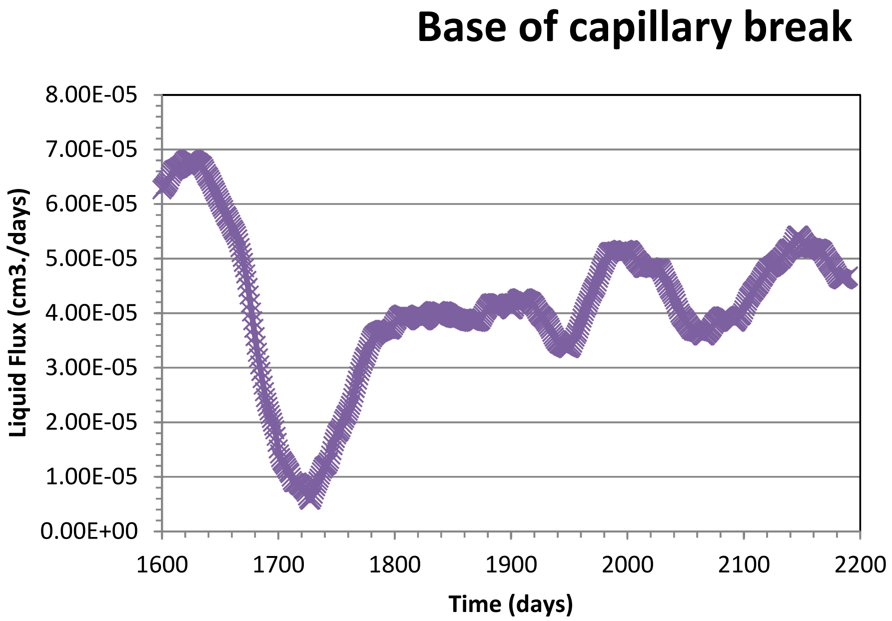

Tailings
Liquid Flux (cm3./days)
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1600
1650
1700
1750
Time (days)

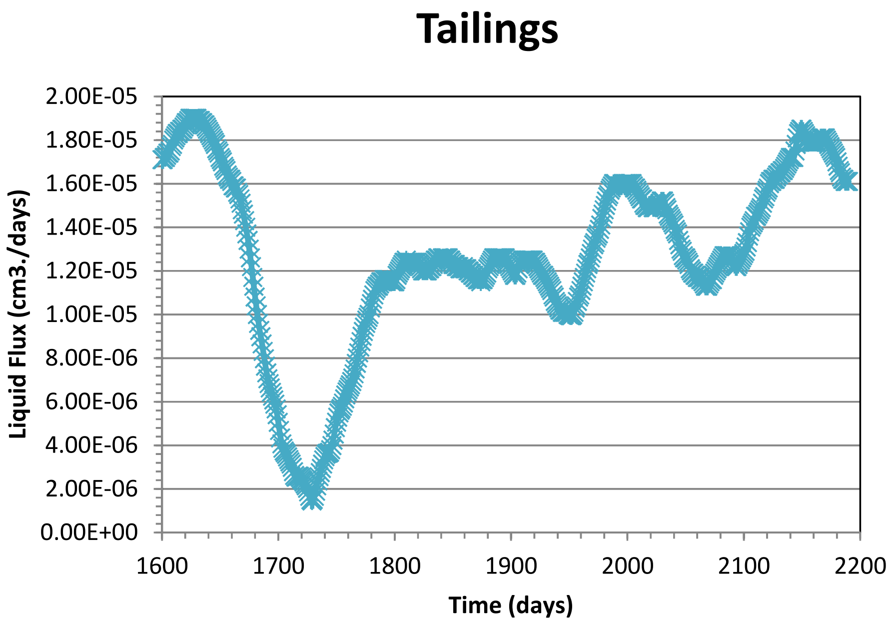
Scenario 14b – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m). Extreme event applied.



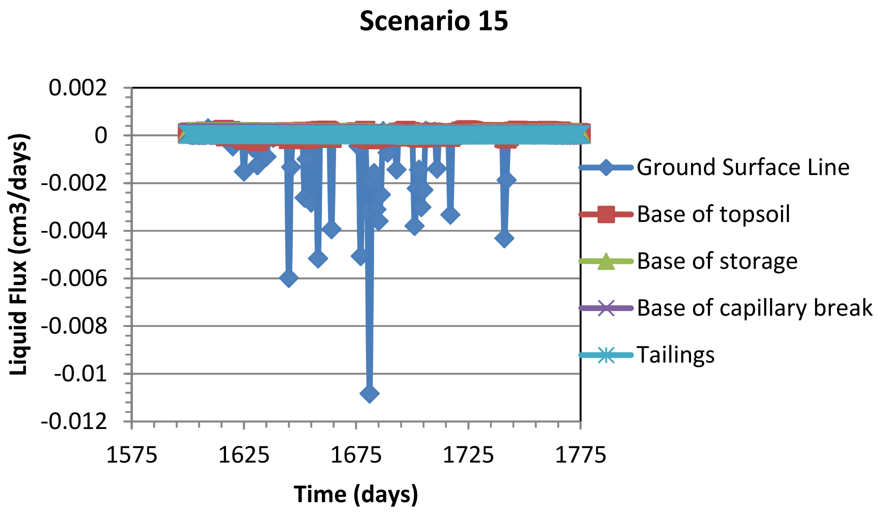


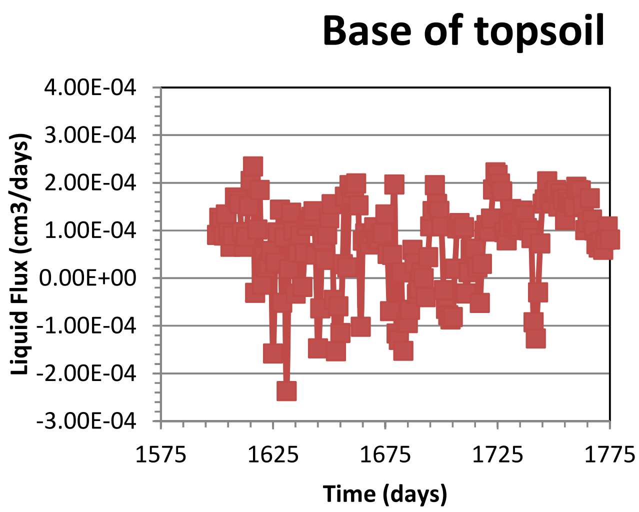

Base of capillary break
Liquid Flux (cm3./days)
8.00E-05
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
1600
1700
1800
1900
2000
2100
2200
Time (days)

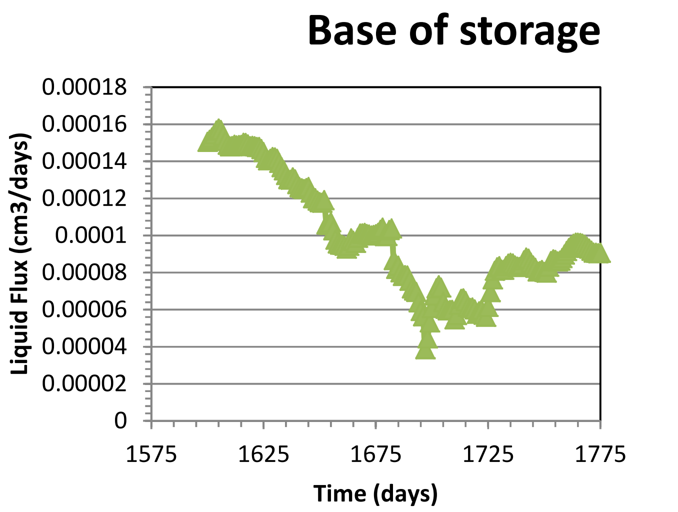

Base of capillary break
Liquid Flux (cm3./days)
8.00E-05
7.00E-05
6.00E-05
5.00E-05
4.00E-05
3.00E-05
2.00E-05
1.00E-05
0.00E+00
1600
1700
1800
1900
2000
2100
2200
Time (days)

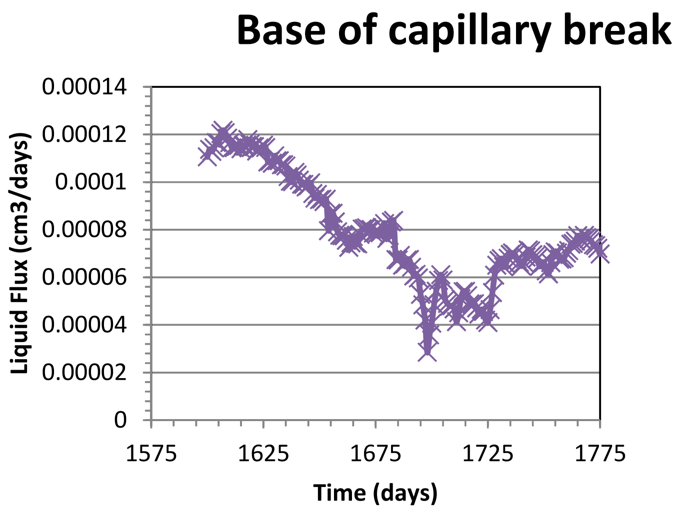

Tailings
Liquid Flux (cm3./days)
2.00E-05
1.80E-05
1.60E-05
1.40E-05
1.20E-05
1.00E-05
8.00E-06
6.00E-06
4.00E-06
2.00E-06
0.00E+00
1600
1700
1800
1900
2000
2100
2200
Time (days)

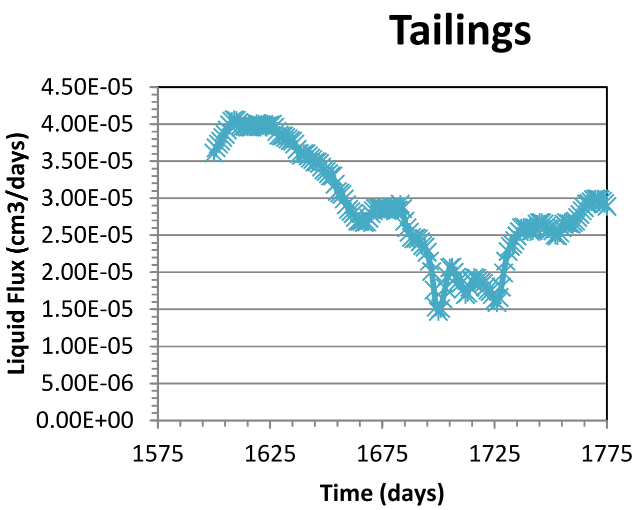
Scenario 15 – Type 3: vegetation; topsoil (15 cm); storage layer (1 m); capillary break (1 m).






Base of storage
Liquid Flux (cm3/days)
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
1575
1625
1675
1725
1775
Time (days)


Base of capillary break
Liquid Flux (cm3/days)
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
1575
1625
1675
1725
1775
Time (days)


Tailings
Liquid Flux (cm3/days)
4.50E-05
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1575
1625
1675
1725
1775
Time (days)