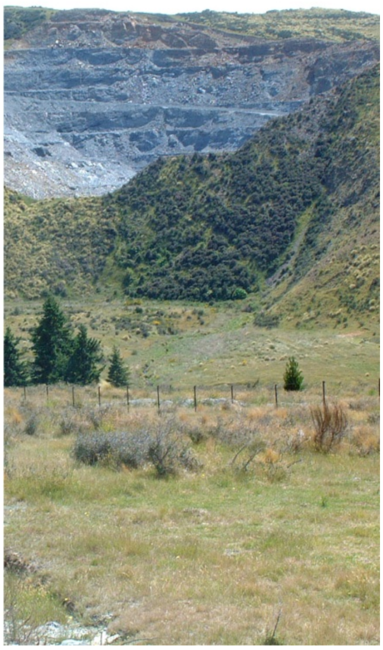
April 2011

## MACRAES PHASE III PROJECT

# Tailings Storage Facility Drainage Rates Following Closure

REPORT

**Submitted to:**
Oceana Gold (New Zealand) Limited



**Report Number.** 0978110-562 R015 vD

**Distribution:**

John Bywater, Oceana Gold (New Zealand) Limited

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# Executive Summary


Oceana Gold (New Zealand) Limited (OceanaGold) has contracted Golder Associates (NZ) Limited (Golder) to carry out groundwater modelling of the Macraes Gold Project (MGP) site in order to determine contaminant mass loads reporting to regional drainage channels at the site. One aspect of site environmental management highlighted by the groundwater modelling is the question of tailings storage facility (TSF) drainage water management following the closure of mining operations at the site.

The existing and proposed TSF's within the MGP site are:

- The existing Mixed Tailings Impoundment (MTI).
- The existing Southern Pit TSF's (SPI) which incorporates the SP10 and SP11 TSF's. The SP10 is currently incorporated within SP11, with the embankment along the northern boundary of SP10 being completely buried by accumulated tailings.
- The proposed Top Tipperary TSF (TTTSF), to be constructed in 2012.

Current and projected sulphate and arsenic loads in water discharging from TSF drainage systems greatly exceed the capacity of nearby creeks to accept and at the same time meet existing consent compliance conditions under most flow conditions (Golder 2011). In addition, these flows are large enough that treatment to improve the water quality followed by discharge of this water would be a very expensive scenario. Mitigation measures to manage these discharge flows have been identified. Existing models of the MGP groundwater system however incorporate limitations in their simulation of the immediate post-closure groundwater systems within the tailings impoundments. Due to these limitations, the degree of uncertainty associated with immediate post-closure projections for drainage flows is relatively large. Specifically, model projections of the rate at which drainage flows may be expected to decline are generally overly conservative.

TSF drainage monitoring records indicate modelled post-closure drainage flows decline substantially slower than occurs in practice. The objective of this report is to document the rates at which drainage flows from existing TSF's have declined following the temporary close of tailings deposition to that TSF. These rates of decline are to be used in assessing the validity of drainage flow decline rates for TSF's simulated in groundwater models for the MGP. The post-closure drainage flow predictions documented in this report are based on an analysis of discharge flows from the toe drains, chimney drains and underdrains constructed around the existing TSF's.

In general, the form of the MTI is similar to that of the proposed TTTSF. Both TSF's have large area to depth ratios and long embankment constrained boundaries. In contrast, the Southern Pit TSF's have lower area to depth ratios and are partially constrained by in-situ schist of the Southern Pit walls. These differences imply the MTI and TTTSF may be expected to have different post-closure drainage characteristics to the SPI.

From the analyses presented in this report it is concluded that discharge flows from the combined TTTSF drainage systems can be expected to decline by between 50% and 90% within two years of the close of tailings deposition. Comparison with the performance of the MTI key drains suggests the decline is more likely to be toward the upper end of this range.

The analyses have incorporated the assumptions that:

- The drainage systems installed in the TTTSF will perform with an efficiency equivalent to or better than those installed in the MTI and the SPI.
- There would be no further pumping of water to the TTTSF following closure.

## ABBREVIATIONS

| | |
|---|---|
| MGP | Macraes Gold Project |
| mRL | Metres above mean sea level |
| MTI | Mixed Tailings Impoundment |
| SPI | Southern Pit Tailings Impoundment, consisting of the combined SP10 and SP11 |
| SP10 | Southern Pit Tailings Impoundment SP10 currently incorporated in SP11 |
| SP11 | Southern Pit Tailings Impoundment SP11 |
| TSF | Tailings Storage Facility |
| TTTSF | Top Tipperary Tailings Storage Facility |

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# 1.0 INTRODUCTION

## 1.1 Background

Oceana Gold (New Zealand) Limited (OceanaGold) operates the Macraes Gold Project (MGP) located in East Otago, approximately 25 km west of Palmerston. The MGP consists of a series of opencast pits and an underground mine supported by ore processing facilities, waste storage areas and water management systems. OceanaGold is currently seeking consents to undertake the Macraes Phase III Project, which entails an expansion of existing opencast pits, the construction of the Top Tipperary Tailings Storage Facility and the construction of new waste rock stacks at the site.

Groundwater modelling of the Macraes Gold Project (MGP) site has been performed to determine contaminant mass loads reporting to regional drainage channels at the site. One aspect of site environmental management highlighted by the groundwater modelling is the question of tailings storage facility (TSF) drainage water management following the closure of mining operations at the site. Current and projected sulphate and arsenic loads in water discharging from TSF drainage systems greatly exceed the capacity of nearby creeks to accept and at the same time meet existing consent compliance conditions under most flow conditions (Golder 2011).

In addition, these flows are large enough that treatment to improve the water quality followed by discharge of this water would be a very expensive scenario. Mitigation measures to manage these initial post-closure discharge flows have been identified and incorporated in base case site water management modelling (Golder 2011).

Existing models of the MGP groundwater system incorporate limitations in their simulation of the immediate post-closure groundwater systems within the tailings impoundments. Due to these limitations, the degree of uncertainty associated with immediate post-closure projections for drainage flows is relatively large. Specifically, model projections of the rate at which drainage flows may be expected to decline are generally overly conservative. TSF drainage monitoring records indicate modelled post-closure drainage flows decline substantially slower than occurs in practice.

Golder Associates (NZ) Limited (Golder) has been retained by OceanaGold to undertake an evaluation of post-closure drainage discharges from TSF's at the MGP. The objective of this report is to document the rates at which drainage flows from existing TSF decline following closure. These rates of decline are to be used in assessing the validity of drainage flow decline rates for TSF's simulated in groundwater models of the MGP.

Large sections of this report have been taken directly from a report by Kingett Mitchell (2005). Updates and supporting material have been based on TSF monitoring records that have become available since that time.[1]

## 1.2 Tailings Drainage Discharge Following Closure

Following TSF closure there are four major components affecting the progressive reduction in discharge flows:

- Initial rapid decreases in flows are a result of the dewatering of the coarse tailings material close to the TSF embankment. Monitored drainage flows indicate this section of the groundwater recovery curve may require up to two years. This initial decrease in drainage flows is complete when a longer term balance is reached between seepage flows out of the coarse tailings and inflows from finer tailings and rainfall recharge.
- The second section of the groundwater recovery curve is based on the much longer period required for the tailings fines to become depressurised and partially dewatered. During this stage the tailings also

[1] This report is provided subject to the limitations presented in Appendix A.

undergo a consolidation process as a reduction in pore water pressure within deeper areas of the tailings mass leads to a reduction in the tailings porosity.

- A steady state groundwater flow regime eventually develops within the tailings mass after consolidation of the tailings has ceased and the general tailings dewatering process has reached the stage where the groundwater table is at a stable long term level.
- Overlain on the groundwater recovery curves and the steady state flow discharges are fluctuations induced by seasonal and storm responses.

The form of the flow recovery curves are also influenced by geometric factors associated with the individual TSF's. These factors include the efficiency and extent of the drainage systems built into the TSF, the depth of accumulated tailings, the area covered by tailings, the nature of the boundaries to the TSF and the nature of the final tailings cap.

In general form, the Mixed Tailings Impoundment (MTI) is similar to the Top Tipperary TSF (TTTSF), the construction of which is planned to start in 2011. Both TSF's have large area to depth ratios and long embankment constrained boundaries. In contrast, the Southern Pit TSF's, SP10 and SP11, which are collectively referred to as the Southern Pit Impoundment (SPI), have lower area to depth ratios and are partially constrained by buried in-situ schist of the Southern Pit walls. These differences imply the MTI and TTTSF may be expected to have different post-closure drainage characteristics to SP10.

As part of the proposed Macraes Phase III development the tailings stored within SP11 are to be excavated and relocated. Tailings stored within and above SP10 are to be reshaped to a stable landform and rehabilitated.

# 2.0 TAILINGS STORAGE FACILITY DRAINAGE RECORDS

## 2.1 Tailings Deposition

The schedule of tailings deposition in the existing TSF's of the MGP is summarised in Table 1. The SP10 TSF is currently incorporated within SP11, with the embankment along the northern boundary of SP10 being completely buried by accumulated tailings.

**Table 1: MGP tailings deposition schedule.**

| Period start | Period end | Active TSF |
|---|---|---|
| 10 February 1992 | 7 February 2002 | MTI |
| 7 February 2002 | 27 May 2003 | SP10 |
| 27 May 2003 | 18 May 2004 | MTI |
| 18 May 2004 | 25 November 2004 | SP10 |
| 25 November 2004 | 22 March 2006 | MTI |
| 22 March 2006 | 13 December 2007 | SP11 |
| 13 December 2007 | 20 May 2009 | MTI |
| 20 May 2009 | 13 February 2010 | SP11 |
| 13 February 2010 | November 2010 | MTI |

## 2.2 Mixed Tailings Impoundment

Discharge flows from the toe drains, chimney drains and underdrains constructed around the MTI have been recorded since January 1990. The discharge flow record for the combined MTI toe, chimney and underdrains prior to 2006 is presented in Figure 1 (Kingett Mitchell 2006). Recorded discharge rates varied considerably during that period, partly due to variations in monitoring procedures. It is, however, considered that the general temporal patterns in discharge flows are reliably recorded.

Maximum recorded drainage flows prior to 2006 occurred during two periods:

- Prior to July 1991
- Between December 1994 and November 1997

Monitoring records indicate the MTI drainage system discharged very large but rapidly decreasing flows during the first year of operations. Subsequently, drainage discharge flows during the following six years gradually increased until 1997. During 1997 the reported drainage discharge flows decreased rapidly, due to:

- The installation of a more reliable flow meter to monitor toe drain discharges, which resulted in the reported flows deceasing abruptly.
- Rupturing of the eastern chimney drain discharge pipe, with discharge flows subsequently reporting to a sump via an open drain that has not been monitored.

Drainage discharge flows during the period 1995 through to 1997 are likely to have been over-reported due to the flow meter inaccuracy, with subsequent flows under-reported due to the discharge pipe rupture.

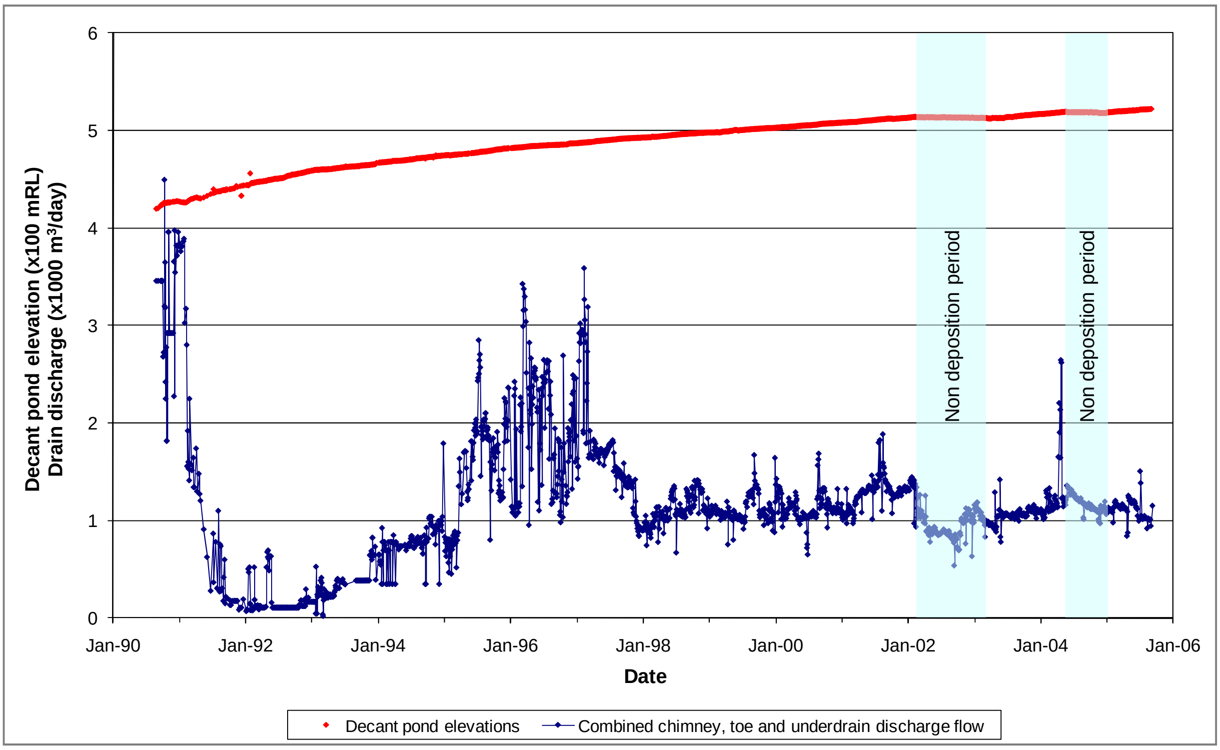


*Figure 1: MTI drainage system discharge record to 2006, excluding mattress and upper tailings drains.*

Drainage monitoring records that have become available since 2006 include separate records for:

- The original drainage systems installed in the MTI, which consist of the tailings underdrains, and toe and chimney drains constructed in the embankment (Figure 2). These drains are collectively referred to as the key drainage system for the MTI.

- Mattress and collector drains constructed in the up-stream embankment raises constructed on top of stored tailings material (Figure 3). These drains are collectively referred to as the upper drainage system for the MTI.

The responses of the key drainage system to the cycling of tailings deposition between the two impoundments appears to have become more muted since 2005, presumably due to increasing depth of drain burial. Since January 2010 the recorded discharge flows have increased at a rate considerably faster than was documented from the previous four years. The recorded flows doubled in less than 12 months. The last time a similar rate of increase was reliably recorded was prior to 1995, during the early period of tailings deposition. This trend is partly due to the renewed deposition of tailings in the MTI from mid 2009. The main contributor to the increased flows is one drain that was not monitored prior to January 2010. This drain may also collect stormwater infiltrating the embankment itself, rather than purely tailings seepage water. As such, the discharges from this drain may be seasonally variable.

The discharge flow responses recorded from the upper drainage system (Figure 3) are much stronger than those recorded from key drains during corresponding periods, apparently due to their shallower depth of burial. The discharge flow patterns for the upper drainage systems since January 2008 suggest the shallowest drainage systems, installed in the MTI at an elevation of 526 mRL, are reducing the volumes of water discharging through drainage systems installed at 505 mRL and 519 mRL. This implies the shallower drainage systems installed in the upstream raises of the MTI embankment are limiting downward pore water seepage in areas close to the embankment.

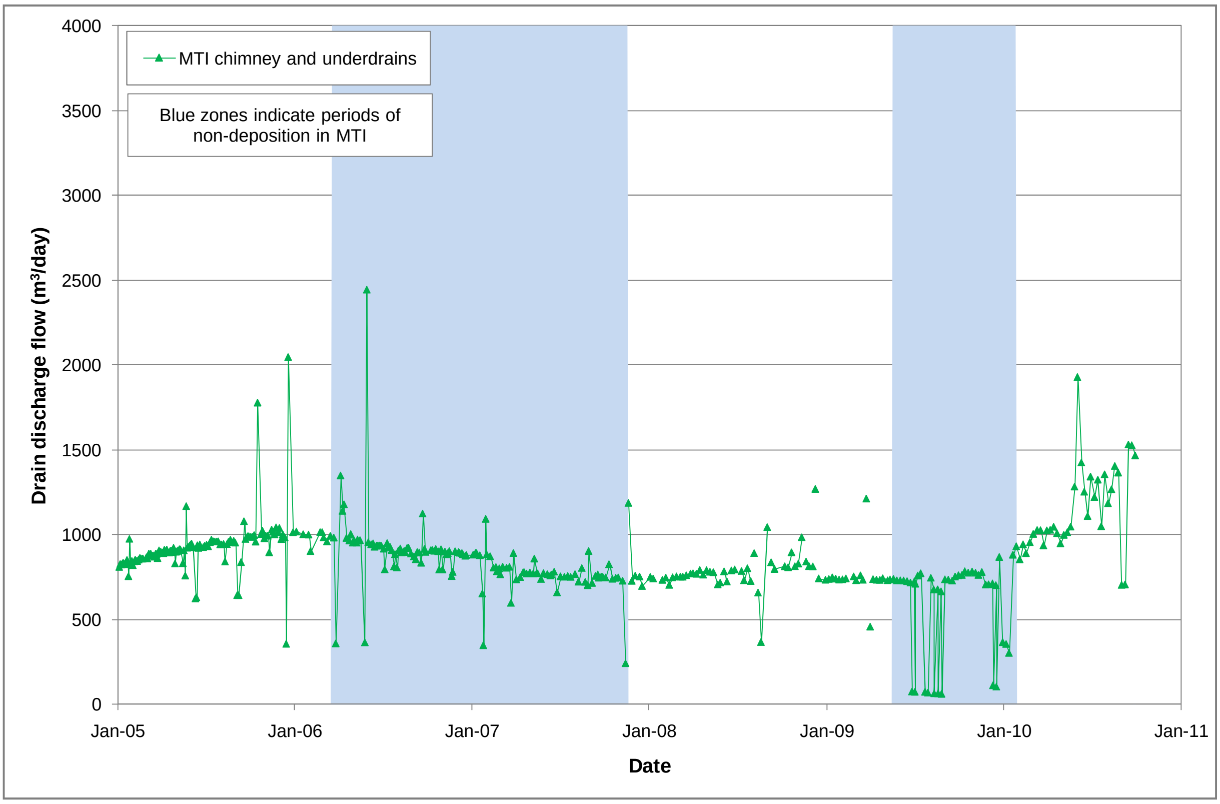


*Figure 2: MTI key drainage system discharge record, 2005 to present, excluding upper tailings drains.*

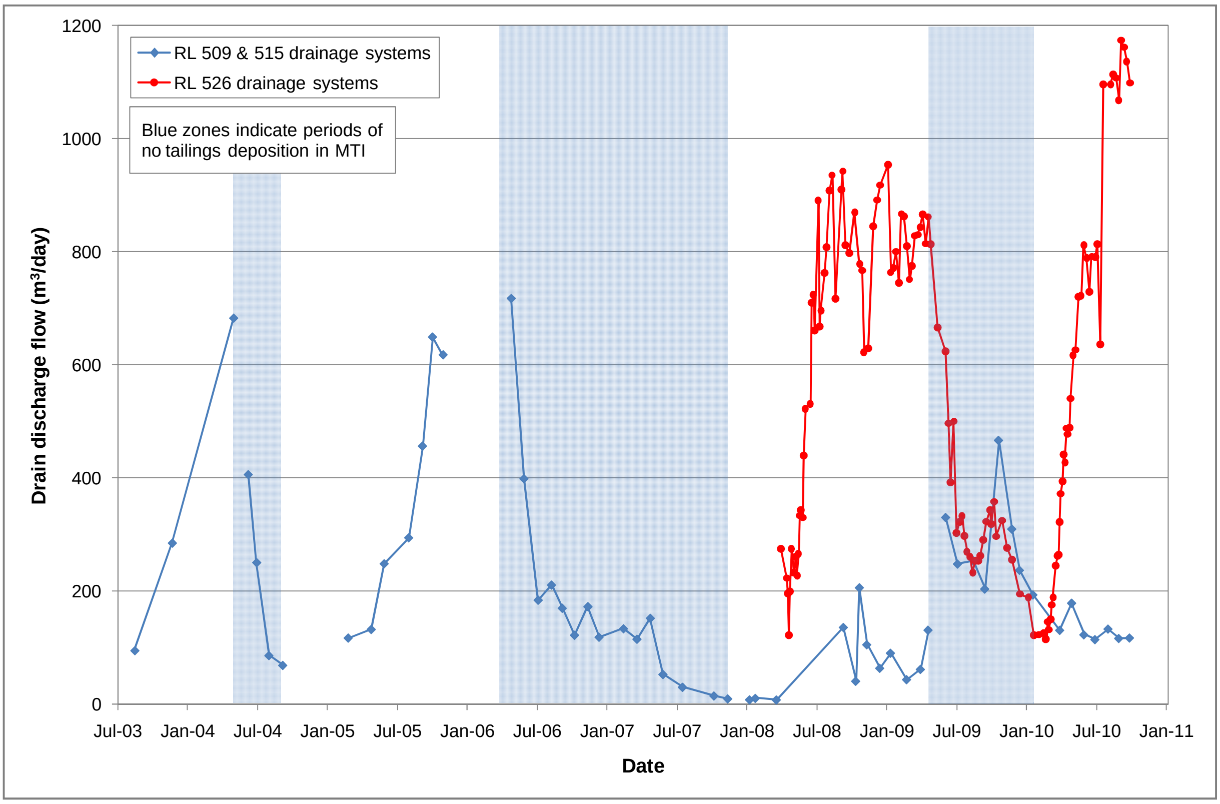


*Figure 3: MTI drainage system discharge record, 2005 to present, upper drainage systems.*

## 2.3 Southern Pit Tailings Impoundments

Drainage monitoring records that have become available since 2006 include separate records for:

- The combined discharge flows for the drainage systems built into SP10 (Figure 4), which is now fully buried by the tailings deposited in SP11.
- The chimney and collector drains and underdrains installed in SP11 (Figure 4). These drains are collectively referred to as the key drainage system for SP11.
- The mattress drains installed to support construction of the upstream raises on the SP11 embankment (Figure 5). These drains are collectively referred to as the upper drainage system for SP11.

Each of the above drainage systems is reacting to the cycling of tailings deposition between the MTI and the SPI. As the drainage systems become more deeply buried by the rising level of tailings in the TSF, the response to changes in tailings deposition becomes muted. This pattern of reducing response is similar to that recorded from the MTI.

In the case of the upper SP11 drainage system, the discharge rates peaked at slightly less than 600 $m^3$/day in February 2010 and have subsequently declined to the extent that the most recent records indicate no discharge is occurring (Figure 5). A lack of discharge indicates the groundwater level within the tailings has dropped below the elevation of the mattress drains.

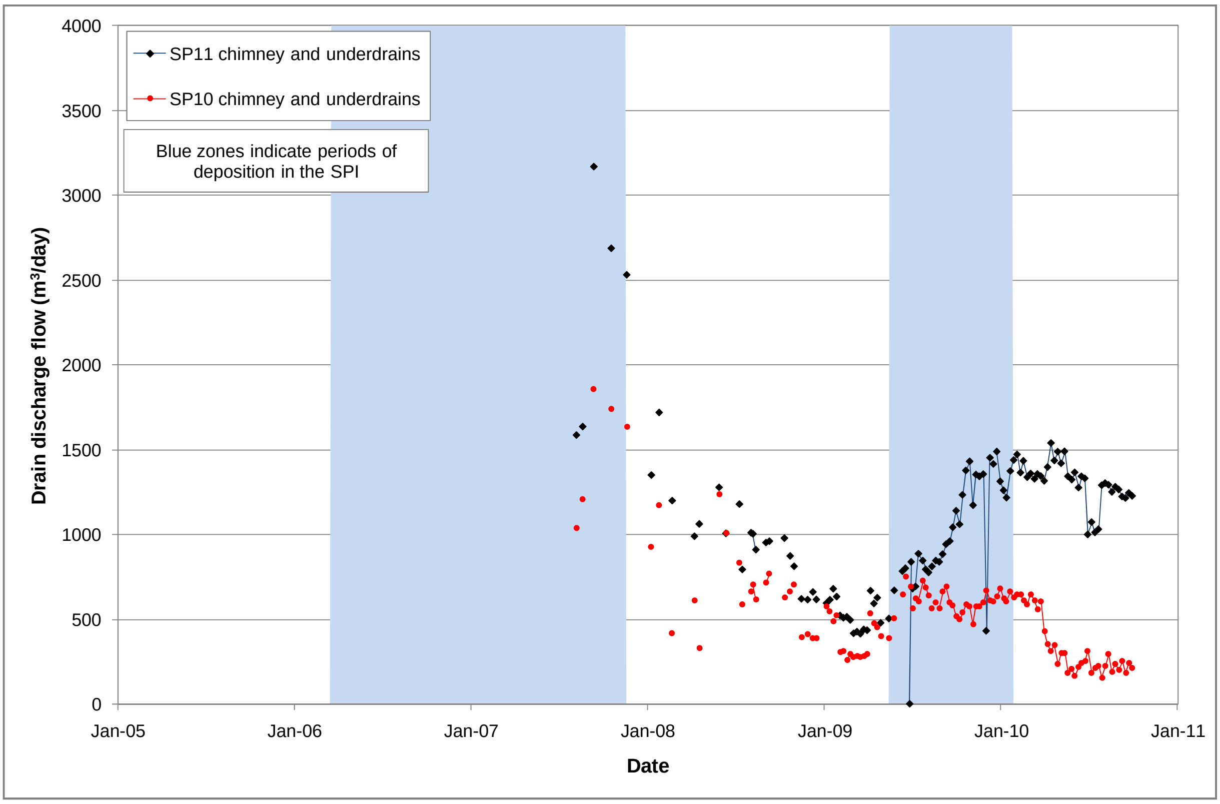


*Figure 4: SPI key drainage system discharge record, 2005 to present, excluding mattress and upper tailings drains.*

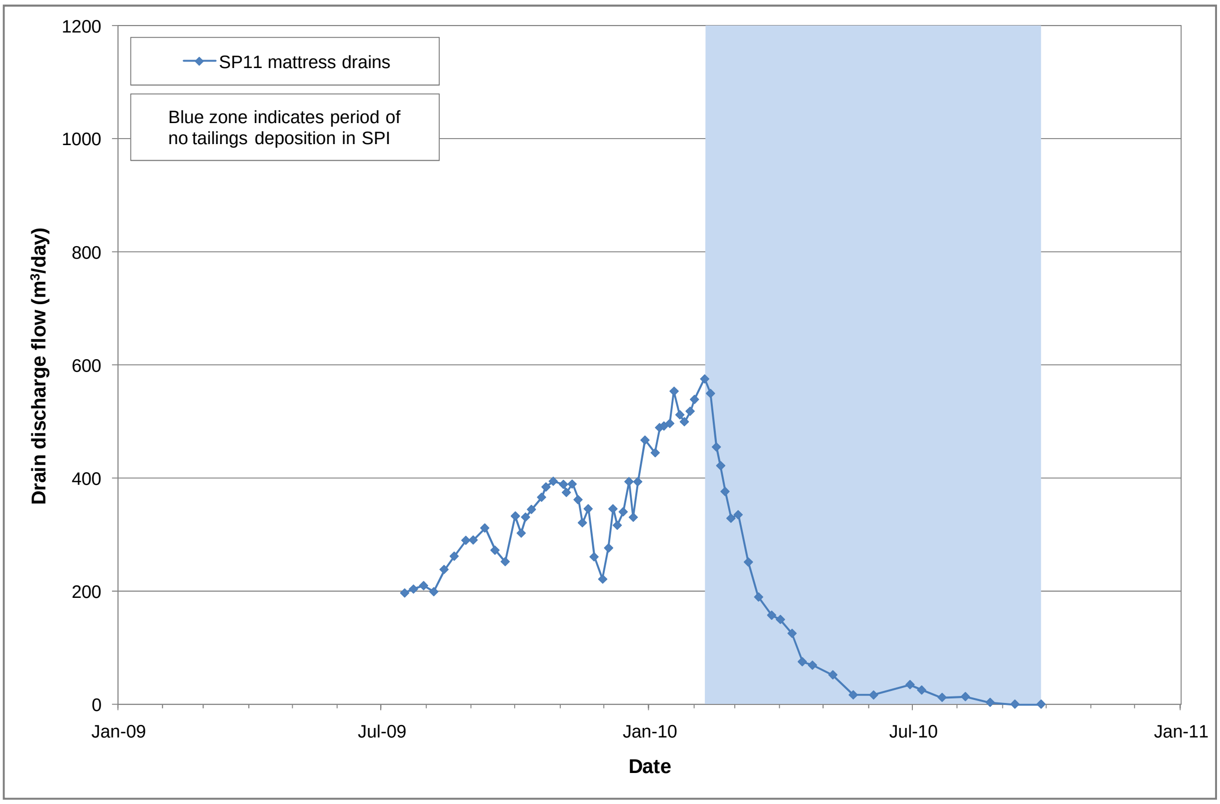


*Figure 5: SP11 mattress (upper) drain system discharge record, 2009 to present.*

## 2.4 Post-closure Drainage Recovery

Since 1997 discharge flows from the drainage systems built into the MTI embankment and installed at the base of the tailings mass have generally increased. Distinct decreases in discharge flows have however occurred during periods when tailings were being deposited in the SPI. The same has also applied to the SPI during periods when it was being rested and deposition was focused on the MTI.

A comparison of the rates at which drainage discharge flows decline during TSF resting periods has been undertaken. Not all of the available discharge decline records have been assessed as some show anomalous changes in flows during the period in which a relatively smooth decline curve could be expected. In some cases these changes are due to maintenance work being carried out to clear specific drains, while in others the reason for the change is unclear. This selection of the data to be analysed could introduce an unintended bias in the outcomes. There is, however, no indication that intensive analysis of the excluded data would result in the conclusions of this report being substantially changed.

The drain flow decline curves for the key MTI drainage systems are presented in Figure 6. The decreases from MTI rest periods in 2002 and 2004 follow similar gradients, whereas the flow decline recorded during a rest period starting in 2006 was considerably slower. As discussed above, this slower decline in drain flows is expected to be due to deeper burial of the key drainage systems within the MTI.

Comparing the MTI key drain flows during the rest periods to the flows recorded immediately prior to the close of tailings deposition, both the 2002 and 2006 records indicate a rapid decrease in flows during the initial 20 days following closure (Figure 7). The 2004 record did not display the same initial decrease in flows. Extrapolation of all three records along the fitted exponential curves indicates a decline in discharge flows of more than 50% could be expected within a period of two years provided tailings deposition did not resume.

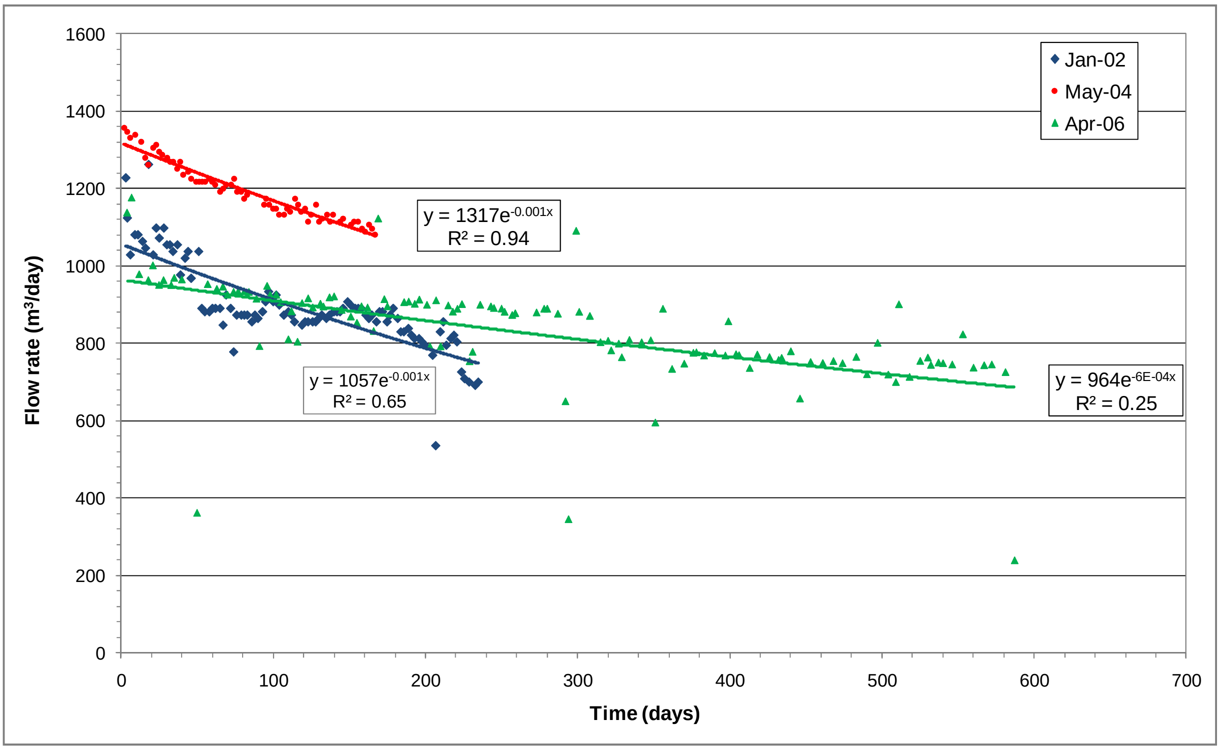


*Figure 6: Discharge flow decreases from MTI key drains during TSF resting periods.*

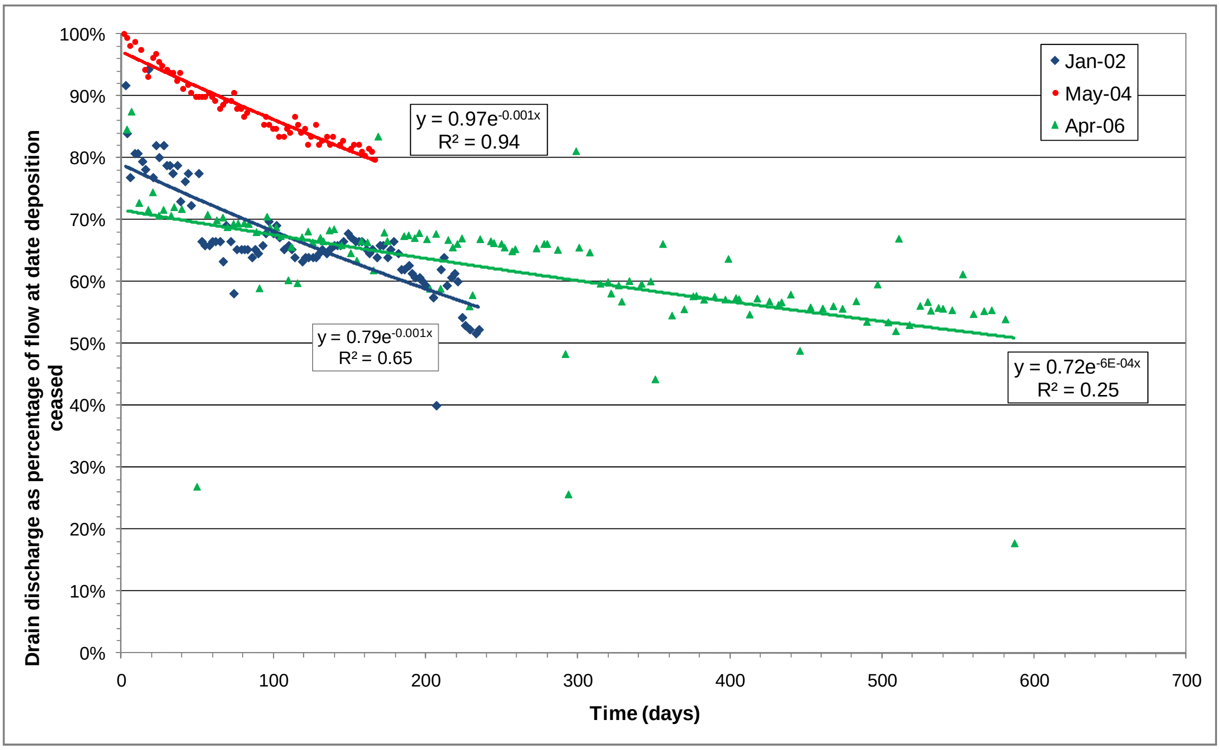


*Figure 7: Percentage decreases in drainage discharges from MTI key drains during TSF resting periods.*

Declines in discharge flows from key SPI drainage systems were recorded during a rest period for the SPI starting in 2007. The key drainage systems installed in both SP10 and SP11 reacted to the change in recharge with substantial declines in discharge flows (Figure 8). Comparing the SPI key drain flows during this rest period to the flows recorded immediately prior to the close of tailings deposition indicates flows declined by more than 80% within two years (Figure 9).

The declines in flows recorded for the upper drainage systems in the MTI (Figure 10) and SP11 (Figure 11) indicate the decrease rates are greater than those for the deeper drainage systems, although the absolute flows are not as great. Comparing the upper drainage system flows during rest periods for both TSF's to the flows recorded immediately prior to the close of tailings deposition indicates flows declined by more than 90% within two years and in some cases within one year (Figure 12).

## 3.0 DISCUSSION

The proposed TTTSF is more similar to the MTI in form than to the SPI. Specifically, it has a larger area to depth ratio and is not confined by intact pit walls at any point. With respect to the reactions of drainage systems to changes in tailings deposition, the TTTSF is most comparable to the first 10 operational years of the MTI. During this period however deposition of tailings to the MTI did not cease for any substantial period of time.

A direct comparison of drainage flows between the MTI and the TTTSF should be treated with caution as several factors differ between the two TSF's. These factors include the topography of the valleys, the ratios between TSF areas, embankment lengths and embankment heights, the layouts of underdrain systems and the nature of the embankment construction.

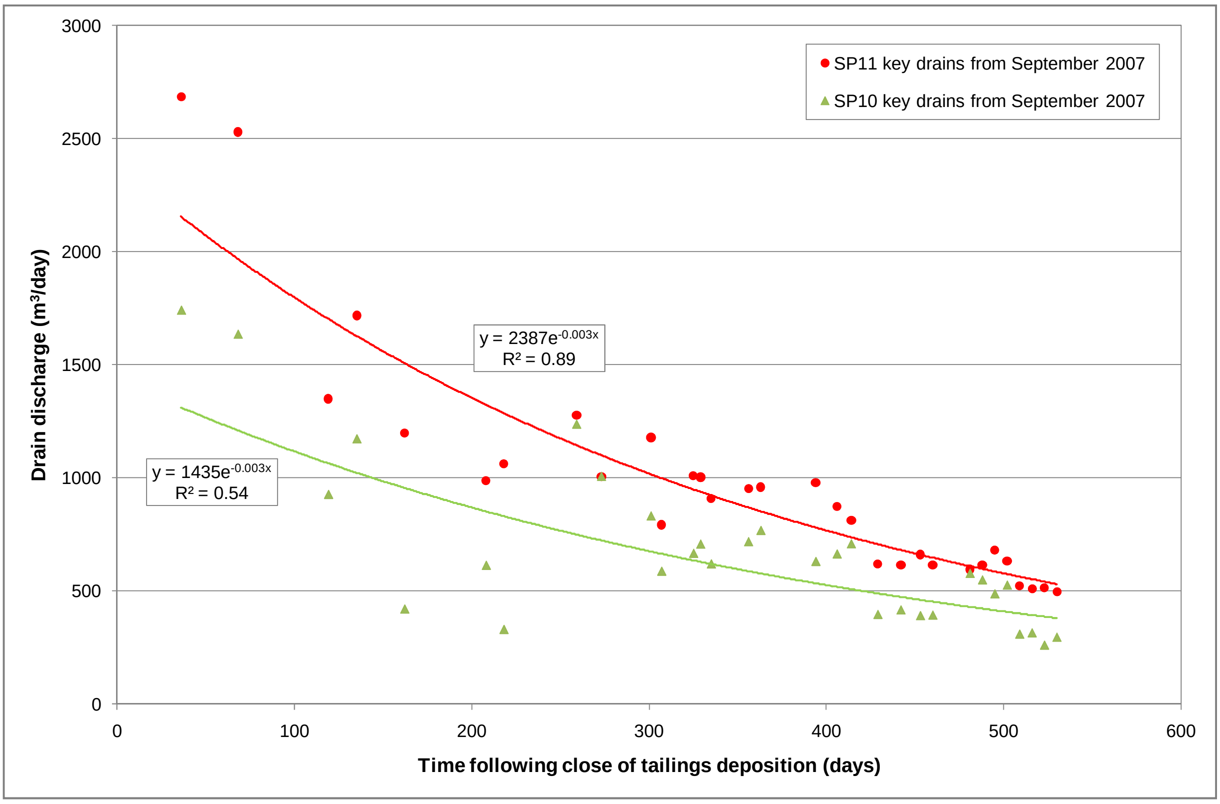


*Figure 8: Discharge flow decreases from SPI key drains during TSF resting periods.*

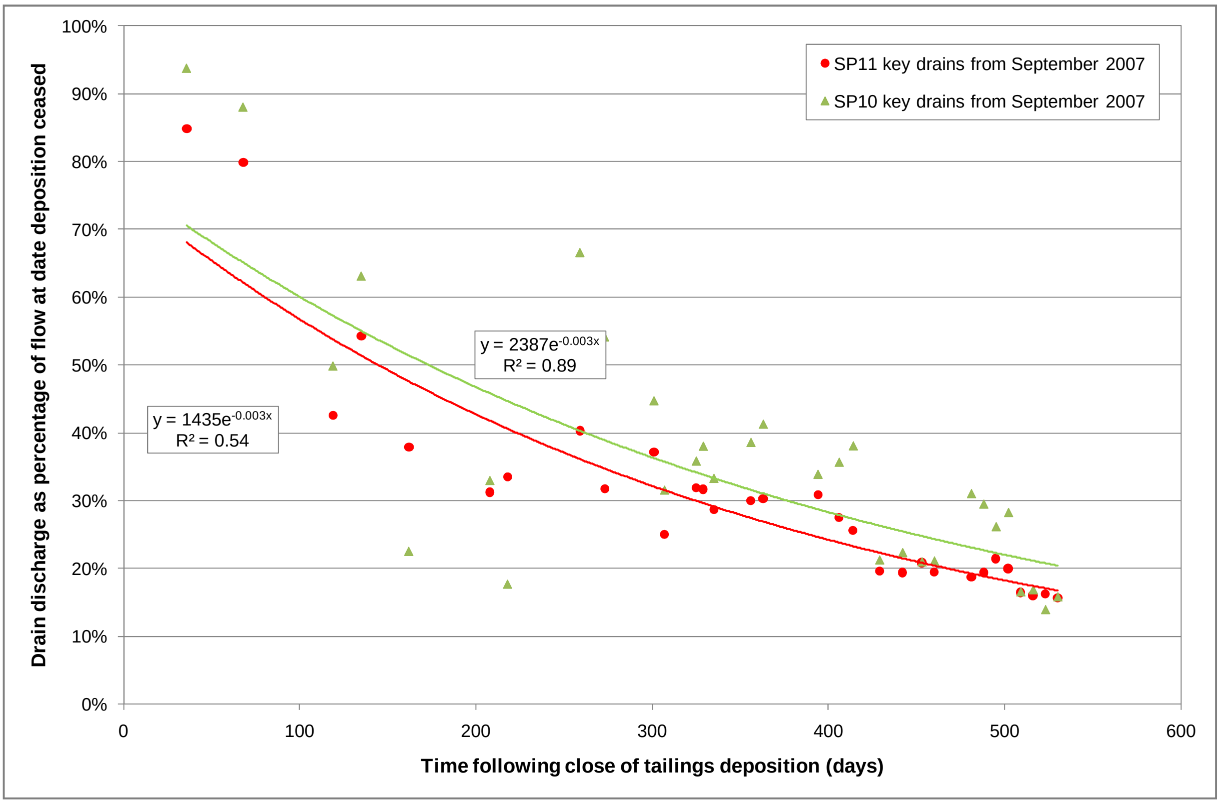


*Figure 9: Percentage decreases in drainage discharges from SPI key drains during TSF resting periods.*

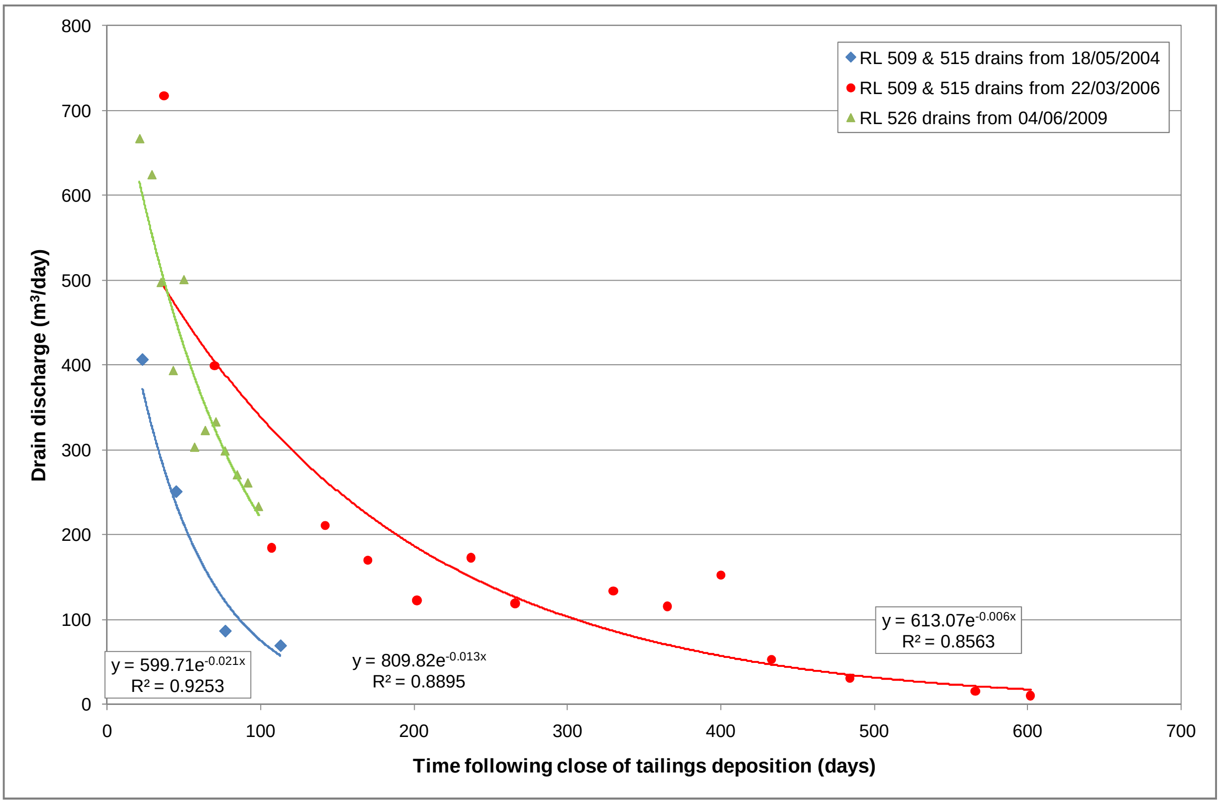


*Figure 10: Discharge flow decreases from MTI upper drainage systems during TSF resting periods.*

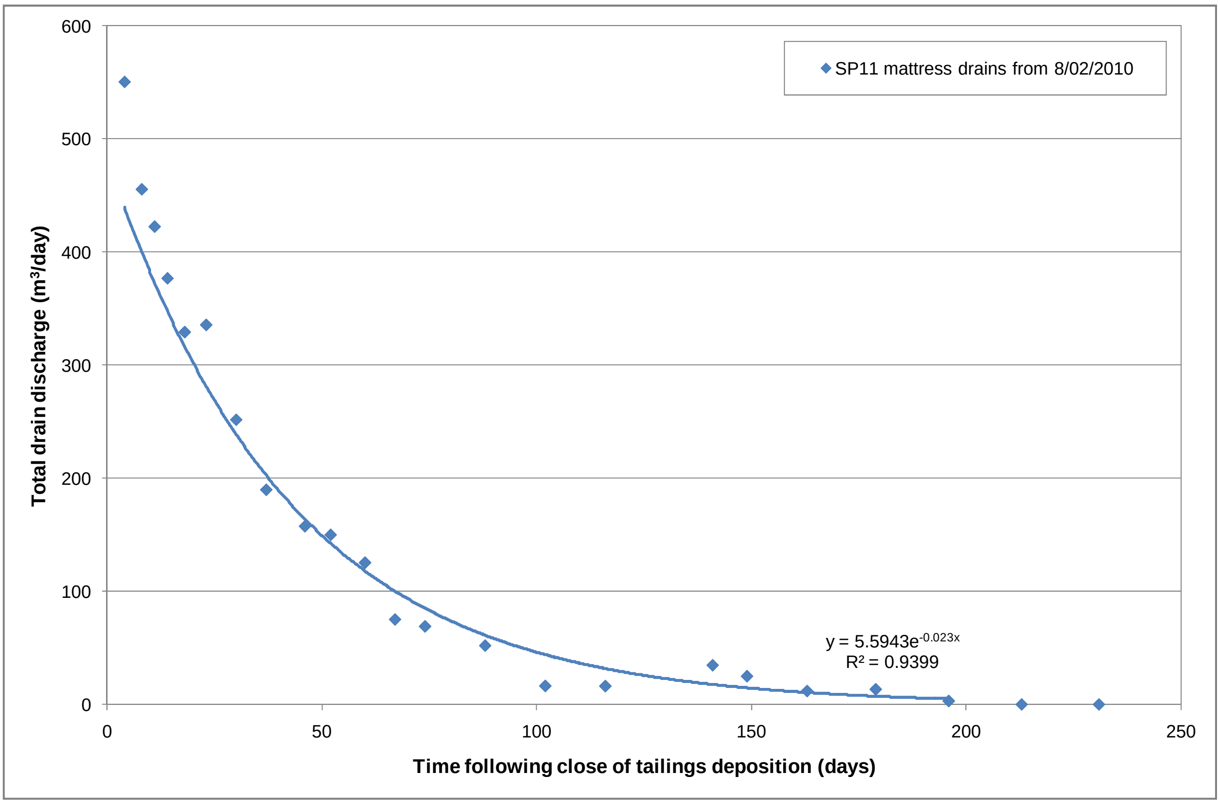


*Figure 11: Discharge flow decreases from SPI upper drainage system during TSF resting period.*

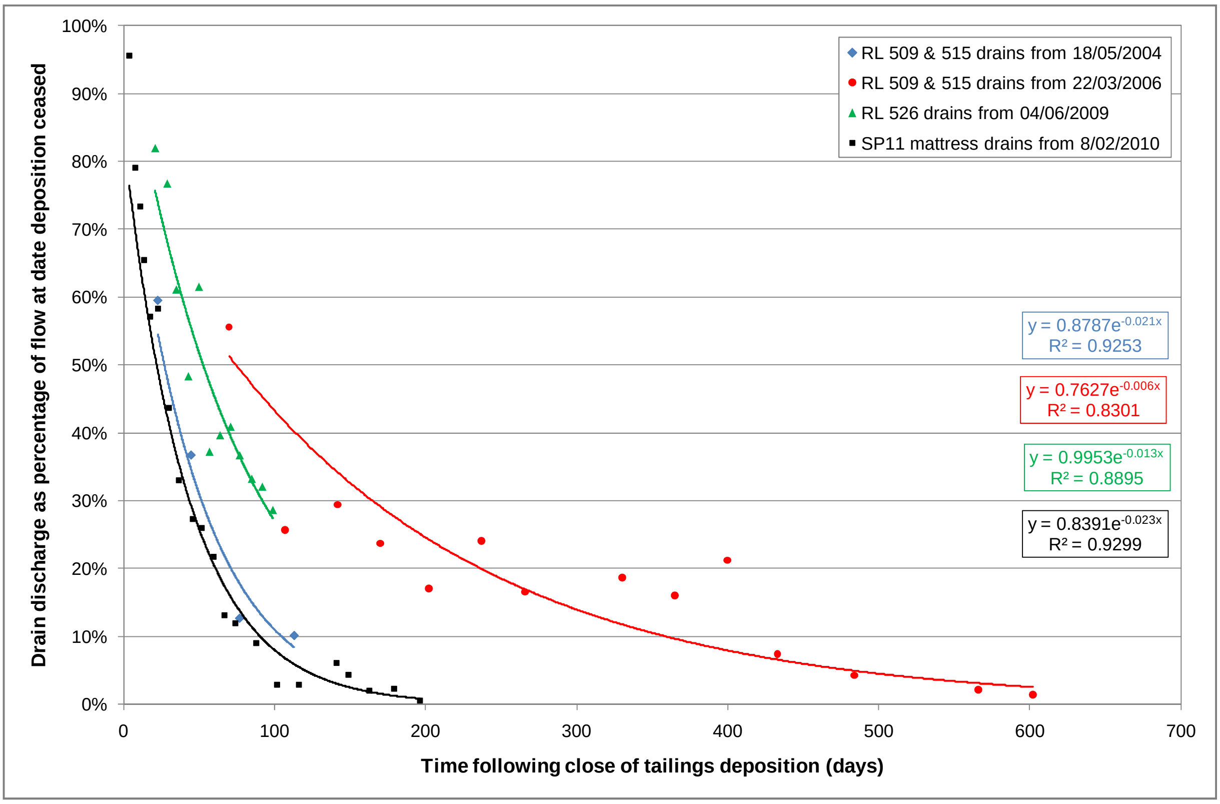


*Figure 12: Percentage decrease in drainage discharges from MTI and SPI upper drains during TSF resting periods.*

It is assumed that the drainage systems installed in the TTTSF will perform with an efficiency equivalent to or better than those installed in the MTI and the SPI. On that basis, the declines in flows exhibited by the following MTI drainage systems are likely to be most indicative of post-closure flows from the TTTSF drainage systems:

- MTI key drains during the 2002 and 2004 TSF rest periods
- MTI and SPI upper drainage systems

The upper drainage systems are likely to be representative of areas of the TTTSF embankment which are to be less than approximately 10 m in height. Underdrains and the chimney drains to be installed in the main Tipperary Creek valley are likely to produce post-closure flow recovery curves that are closer to those of the MTI key drains.

The maximum depth of tailings stored in the MTI by 2002 was approximately 100 m, which compares to the maximum height of the TTTSF embankment from the upstream toe of approximately 60 m. It is therefore likely that the rate at which discharges from the MTI key drains decreased during a TSF rest period would be slower than the decline in flows from the main chimney and underdrains planned for the TTTSF.

The cap design for the TTTSF could affect the rate of drainage flow decline if the cap resulted in an increase in natural recharge to the tailings above that which applied to the MTI and SPI during their rest periods. Golder understands that OceanaGold intends to cap the TSF's in such a way as to minimise long term recharge to the tailings.

# 4.0 CONCLUSIONS

From the analyses presented in this report it is concluded that discharge flows from the combined TTTSF drainage systems can be expected to decline by between 50% and 90% within two years of the close of tailings deposition. Comparison with the performance of the MTI key drains suggests the decline is more likely to be toward the upper end of this range.

The analyses have incorporated the assumptions that:

- The drainage systems installed in the TTTSF will perform with an efficiency equivalent to or better than those installed in the MTI and the SPI.
- There would be no further pumping of water to the TTTSF following closure.
- The tailings cap would not lead to a rate of natural recharge to the tailings above that experienced by the MTI and SPI during their respective rest periods.

# 5.0 REFERENCES

Golder 2011. Macraes Phase III Project. Site wide surface water model. Report produced for OceanaGold (New Zealand) Limited by Golder Associates (NZ) Limited. March 2011. Report number 0978110-562 R008.

Kingett Mitchell 2005. Macraes Gold Project tailings impoundment closure water management: tailings seepage assessment. Report produced for OceanaGold (New Zealand) Limited by Kingett Mitchell Limited. December 2005.

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# APPENDIX A

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