

12.4 Predicted impact on alluvial water budgets and baseflow

The Project will not mine through any part of the Hunter River alluvium or the Saddlers Creek alluvium. Therefore, direct rainfall recharge to the alluvium and the ability of the alluvium to store and transmit water will be unaffected by the Project.

The pre-mining hydraulic gradient already promotes upward leakage of Permian (bedrock) groundwater into the Hunter River alluvium and Saddlers Creek alluvium. Evidence of this process has been confirmed by groundwater head measurements and the occurrence of moderate salinity within some sections of the alluvium.

The predicted change to the net leakage of groundwater from the Permian coal measures into the alluvium of Saddlers Creek and the Hunter River is shown on Figure 33. The predicted change to the baseflow of the Hunter River and Saddlers Creek is shown in Figure 34.

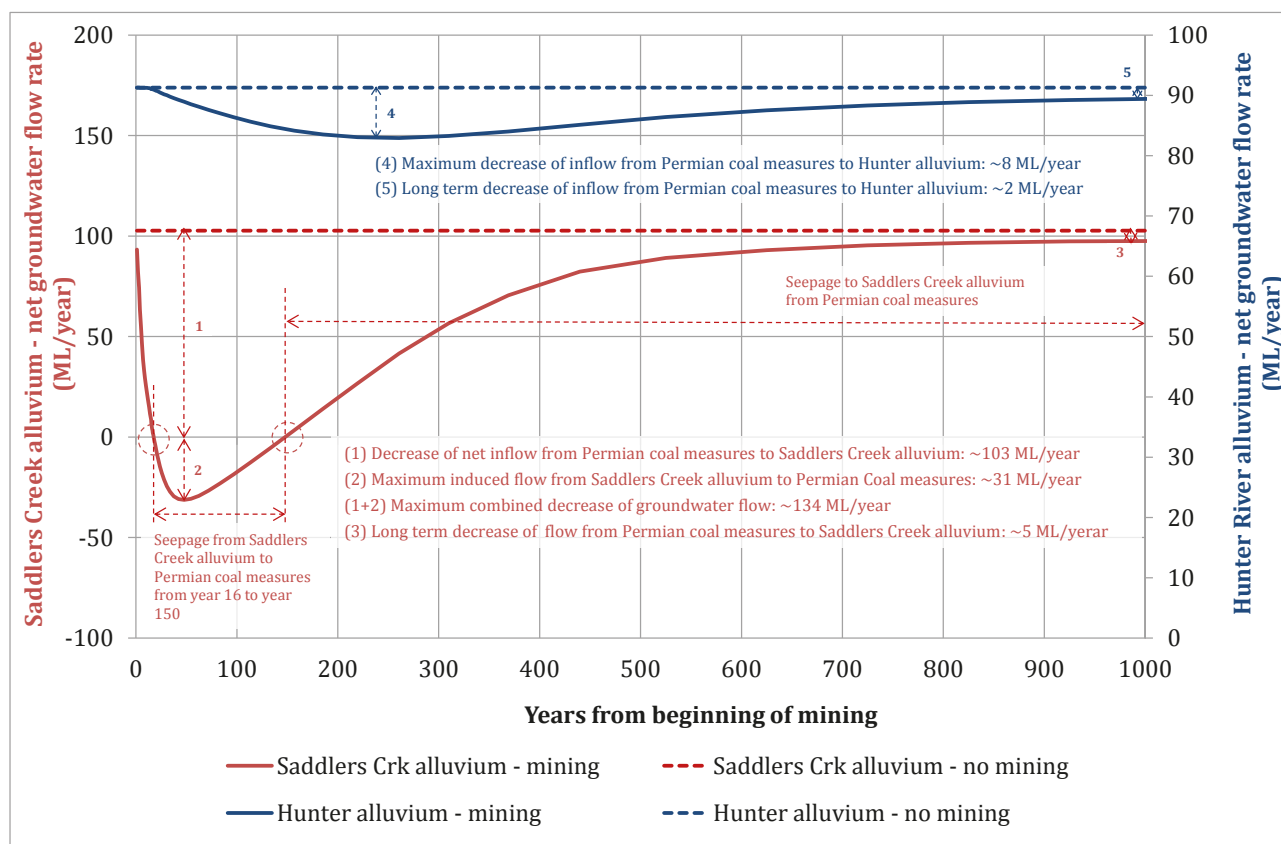


Figure 33 Predicted change to bedrock leakage to alluvium

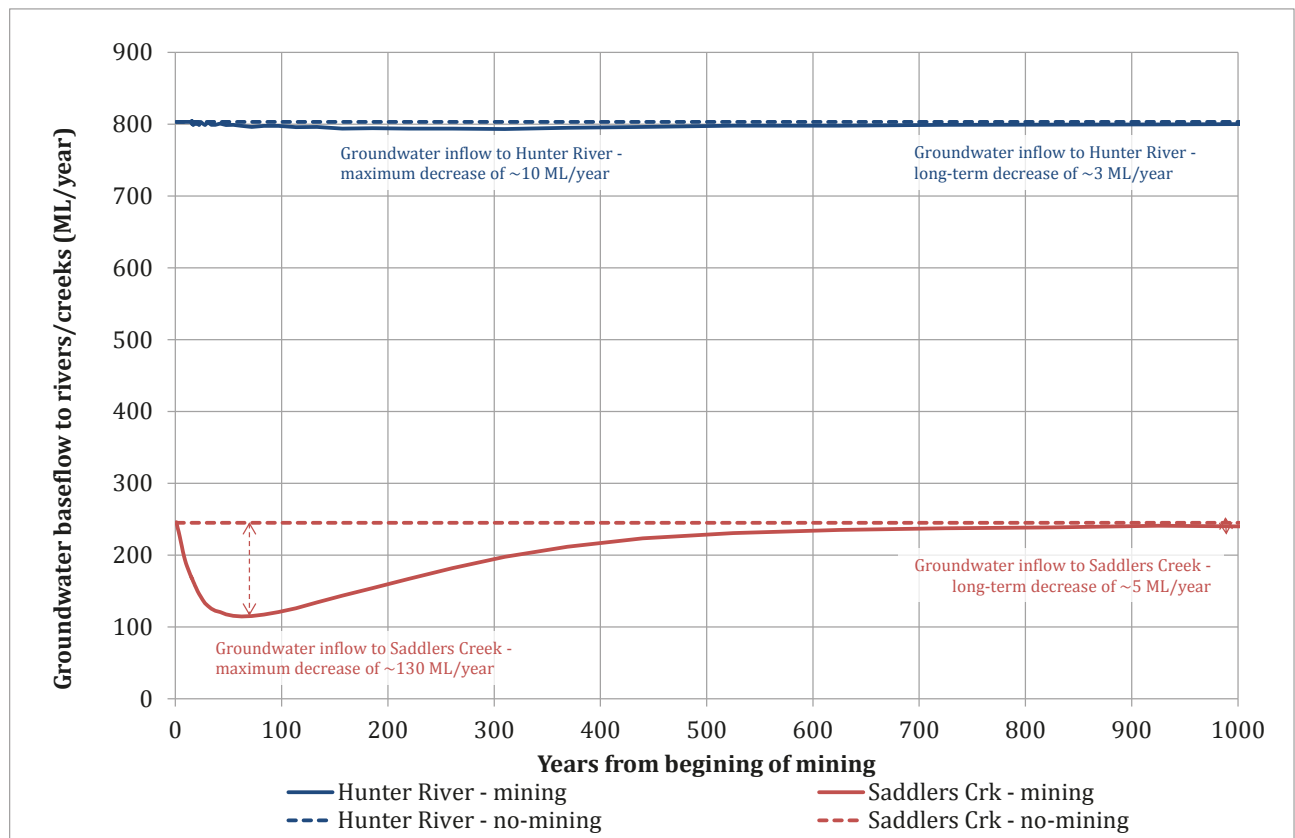


Figure 34 Predicted change to creek and river baseflow

12.4.1 Leakage to Saddlers Creek alluvium

The rate of change in upward leakage from bedrock into the Saddlers Creek alluvium is predicted to be greater than that predicted for the Hunter River alluvium. This is due to the proximity of Saddlers Creek alluvium to the Project. The rate of upward leakage of the bedrock groundwater into the Saddlers Creek alluvium is predicted to progressively reduce during mining as the Project progresses below the water table, reducing the hydraulic gradient towards the alluvium.

The results presented in Table 15 show the rate of upward leakage from the bedrock into the Saddlers Creek alluvium is predicted to be progressively reduced by 94 ML/year by the last year of mining (Year 15).

The hydraulic gradient is predicted to further decline after mining as the groundwater regime adjusts towards a new equilibrium. Leakage to Saddlers Creek alluvium from the bedrock is predicted to cease (maximum change of 103 ML/year) about three years after mining. After this point in time, the hydraulic gradient is predicted to be reversed away from Saddlers Creek and groundwater will leak from the alluvium into the underlying Permian coal measures.

The maximum impact is predicted to occur about 30 years post mining (Figure 33). This is because the extent of drawdown will continue to grow somewhat after mining, and the hydraulic gradient established away from the creek will continue to increase as a result. The hydraulic gradient is predicted to be returned towards Saddlers Creek about 150 years after mining.

The predicted impacts on the water budget of Saddlers Creek alluvium post mining are discussed further in Section 13.6.1.

Table 15 Predicted bedrock leakage to Saddlers Creek alluvium – during mining

Year from beginning of mining	Leakage from bedrock to Saddlers Creek alluvium (ML/year)	Maximum change (i.e. loss) (ML/year)
Pre-Mining	103 (towards alluvium)	-
0 - 4	103 - 63	0 - 39
4 - 6	63 - 46	39 - 57
6 - 9	46 - 29	57 - 74
9 - 12	29 - 18	74 - 85
12 - 15 (end of mining)	18 - 9	85 - 94

12.4.2 Baseflow to Saddlers Creek

Baseflow from the alluvium to Saddlers Creek is predicted to be progressively reduced by up to 76 ML/year by the end of mining (Table 16).

However, the maximum decline is predicted to occur about 50 years post mining (Figure 34). This is because the extent of drawdown will continue to grow somewhat after mining, and the hydraulic gradient established away from the creek will continue to increase as a result. The hydraulic gradient is predicted to be returned towards Saddlers Creek about 150 years after mining.

The predicted impacts to baseflow within Saddlers Creek post mining are discussed further in Section 13.6.2.

Table 16 Predicted baseflow to Saddlers Creek – during mining

Year from beginning of mining	Baseflow from alluvium to Saddlers Creek (ML/year)	Maximum change (i.e. loss) (ML/year)
Pre-Mining	245	-
0 - 4	245 - 226	0 - 19
4 - 6	226 - 212	19 - 33
6 - 9	212 - 193	33 - 52
9 - 12	193 - 180	52 - 65
12 - 15 (end of mining)	180 - 169	65 - 76

12.4.3 Leakage to Hunter River alluvium

The rate of upward leakage of bedrock groundwater into the Hunter River alluvium is predicted to remain unchanged during the mining period (Table 17). Reduction of the upward leakage is predicted to commence six years after mining has finished. The predicted impacts to upward leakage to the Hunter River alluvium post mining are discussed further in Section 13.6.2.

Table 17 Predicted bedrock leakage to Hunter River alluvium – during mining

Year from beginning of mining	Leakage from bedrock to Hunter River alluvium (ML/year)	Maximum change (i.e. loss) (ML/year)
Pre-Mining	91	-
0 - 4	91 - 91	0 - 0
4 - 6	91 - 91	0 - 0
6 - 9	91 - 91	0 - 0
9 - 12	91 - 91	0 - 0
12 - 15 (end of mining)	91 - 91	0 - 0

12.4.4 Baseflow to Hunter River

Baseflow to the Hunter River is predicted to not be impacted during mining (Figure 34 and Table 18). The predicted impacts to baseflow within the Hunter River post mining are discussed further in Section 13.6.4.

Table 18 Predicted baseflow to Hunter River – during mining

Year from beginning of mining	Baseflow from alluvium to Hunter River (ML/year)	Maximum change (i.e. loss) (ML/year)
Pre-Mining	803	-
0 - 4	803 - 803	0 - 0
4 - 6	803 - 803	0 - 0
6 - 9	803 - 803	0 - 0
9 - 12	803 - 803	0 - 0
12 - 15 (end of mining)	803 - 803	0 - 0

12.5 Predicted impact on groundwater quality

12.5.1 Saddlers Creek alluvium

The existing beneficial use of the Saddlers Creek alluvial groundwater will not be impacted during mining. The Saddlers Creek alluvium will most likely remain too saline for primary industries in the long-term.

The natural upward leakage of water from the Permian coal measures into the Saddlers Creek alluvium is predicted to be reduced as a result of the Project. Rainfall recharge to the Saddlers Creek alluvium will continue and as a result, the groundwater quality within the alluvium is likely to improve as a result of the rainfall dominated recharge.

12.5.2 Hunter River alluvium

The existing beneficial use of the Hunter River alluvial groundwater will not be impacted during mining. The beneficial use will remain classified as primary industry with the main use being for stock watering, and limited irrigation where better water quality water is present.

The groundwater quality within the Hunter River alluvium is highly unlikely to be impacted because the rate of upward leakage from the Permian bedrock is predicted to remain unchanged during the mining period. Rainfall recharge will continue as the dominant recharge source for the Hunter River alluvium.

12.5.3 Permian coal measures

The existing beneficial use of the Permian coal measure groundwater will not be impacted during mining. The generally low yield and poor quality of the groundwater in the coal seams limits its beneficial use and it will remain suitable for primary industry with the main potential use being for stock watering.

Mining induced changes to the hydraulic properties and depressurisation of the strata in the mined area will result in mixing of chemically different groundwater in the overlying and underlying units. Groundwater within the Permian coal measures is known to be moderately saline with a mean TDS concentration of about 3500 mg/L. Therefore, mixing of Permian groundwater is unlikely to significantly change the existing quality and beneficial use of the groundwater. The likelihood of this minor water quality change will decrease with distance from the mining area and reduced rock mass fracturing.

13. Predicted impacts post mining

13.1 Estimate of void water level – Whynot mining area

Post mining, the final landform of the Whynot mining area will consist of re-worked spoil across the entire disturbance area. The spoil will be shaped in a manner that promotes free drainage away from the northern and western mining areas. Drainage from the eastern and central areas will be directed toward a central void area.

Figure 35 shows that after mining, saturation of the backfilled spoil in the Whynot mining area is predicted to take about 245 years before a permanent lake surface develops within the void area. The water level within the void attains a post-mining equilibrium level of 128 mAHD after 800 years. At this elevation, the amount of water entering the void via runoff, direct rainfall, and seepage from the spoil is equivalent to the amount of water lost to evaporation from the void water surface.

The surface water spill height of the modified final void is located at an elevation of 145 mAHD. The freeboard between the spill point of the modified final void design and the surface water elevation is predicted to be about 17 m.

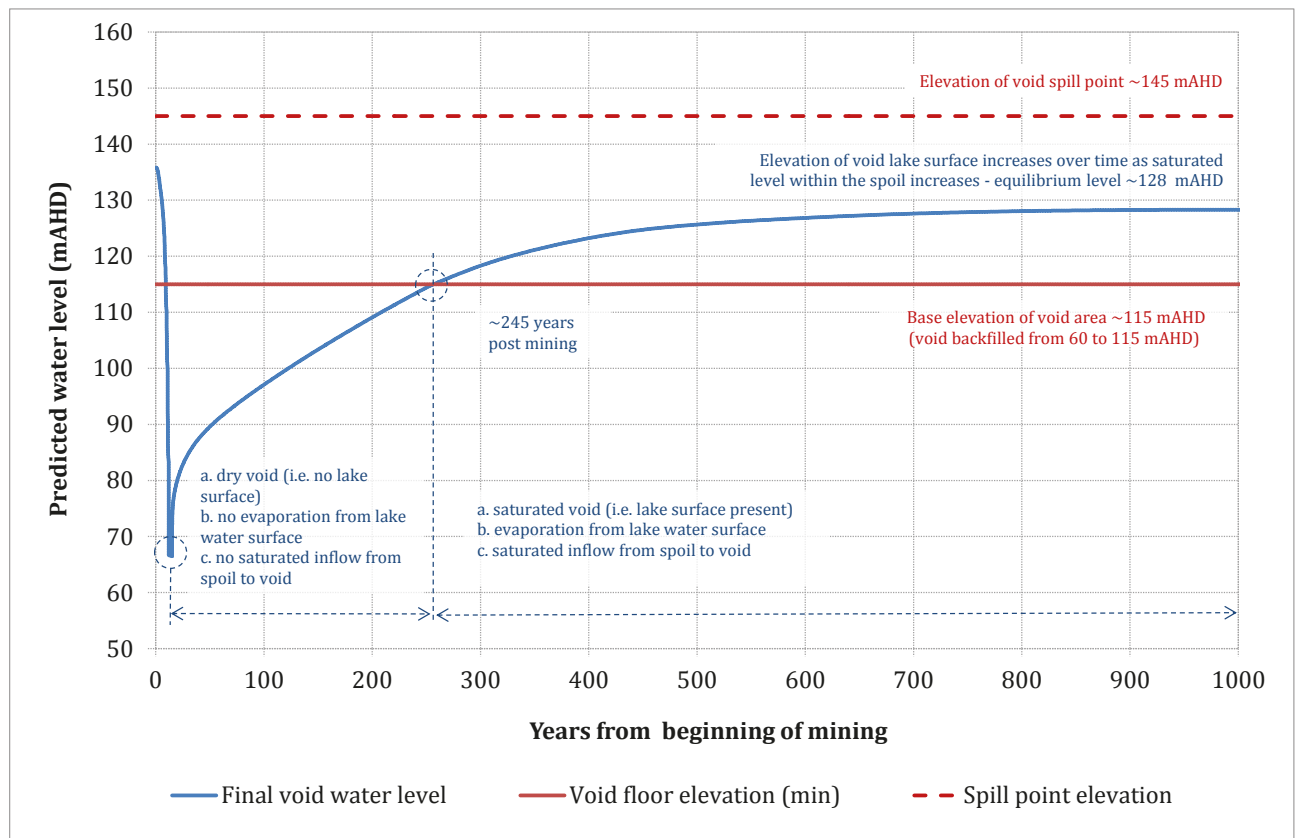


Figure 35 Predicted water level in final void

13.2 Final void water budget – Whynot mining area

The predicted water balance for the void design is presented in Figure 36. The effect of evapotranspiration on the recovering water level in the spoil is predicted to be absent for the first 245 years after mining. This is due to the water level within the spoil being lower than the base of the void area. The absence of evapotranspiration during this period enhances the rate at which the water level recovers within the spoil.

Evapotranspiration from the void area is simulated to commence when the recovering water level in the spoil is within 0.5 m of the base of the void area. Once evapotranspiration commences, the predicted rate increases in response to a progressively increasing surface water area as the void lake develops. The rate of evapotranspiration increases to a maximum of 401 ML/year.

Recharge to the void from direct rainfall and runoff was predicted to be about 214 ML/year. Water movement from the spoil into the void increases from 0 ML/day to a maximum of 188 ML/year to replace surface water in the void that is lost to evaporation.

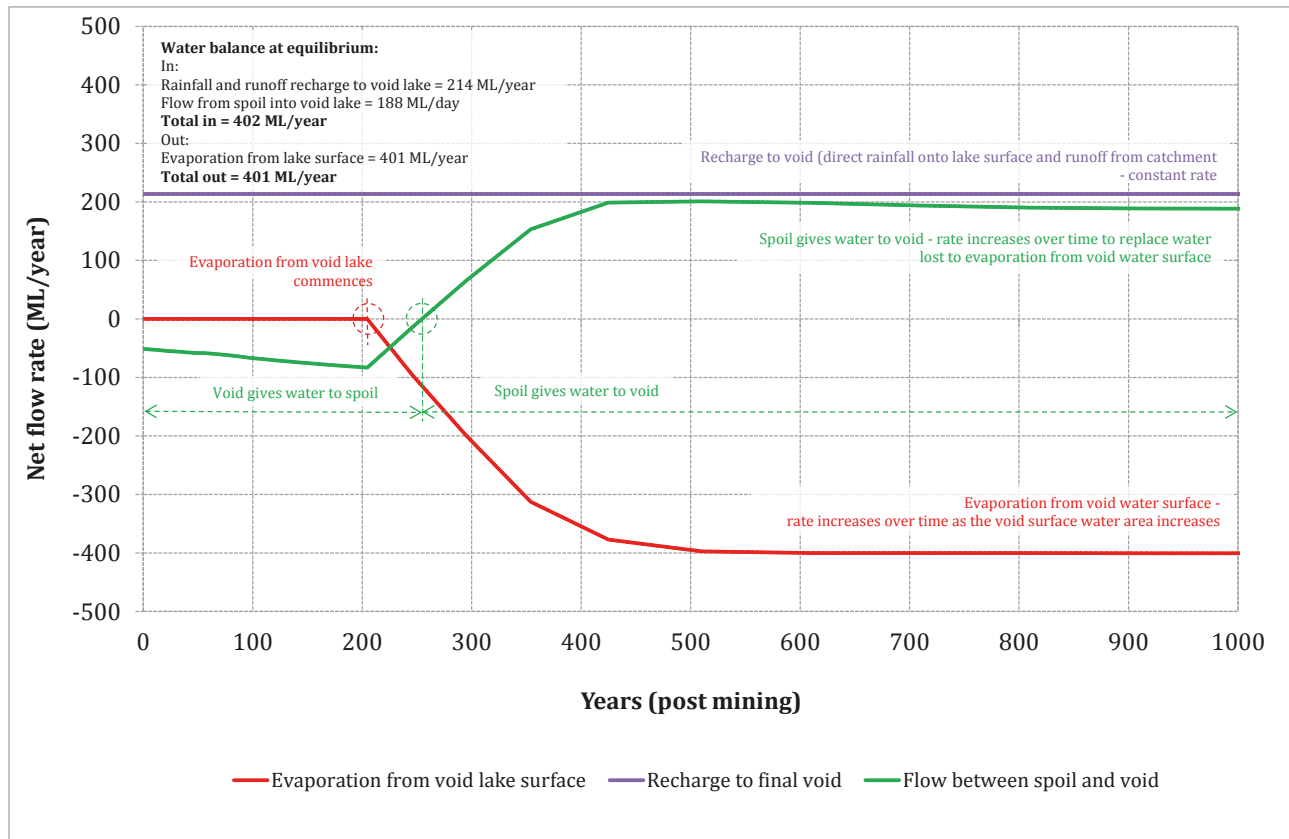


Figure 36 Final void water budget and water level

13.3 Groundwater drawdown, heads, and hydraulic gradients

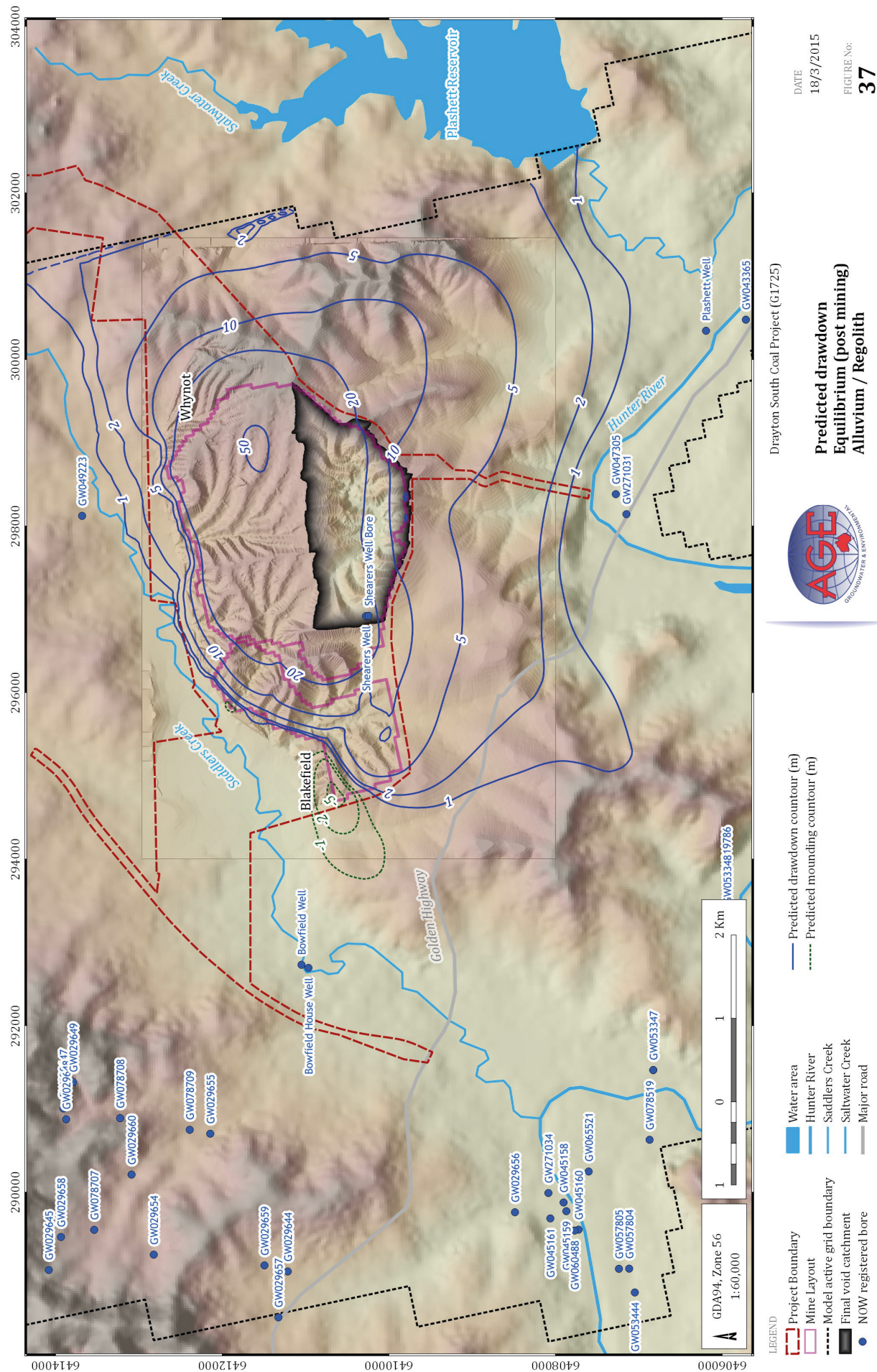
The predicted extent of drawdown after 1000 years post mining (i.e. having reached an equilibrium) is presented in Figure 37 and Figure 38 for Layer 1 and 5, respectively. The long-term drawdown extent is predicted to not intersect the Hunter River alluvium, but water levels within the adjacent Saddlers Creek alluvium will be impacted by declines ranging between 1 m and 2 m.

Figure 39 and Figure 40 show the predicted groundwater heads for Layer 1 and Layer 5 (respectively) 1000 years post mining. The predicted heads have a very flat hydraulic gradient within the spoil areas of Whynot and Blakefield mining areas. This is typical for spoil areas where the hydraulic conductivity of the material is relatively high compared with the surrounding geology (e.g. Permian coal measures).

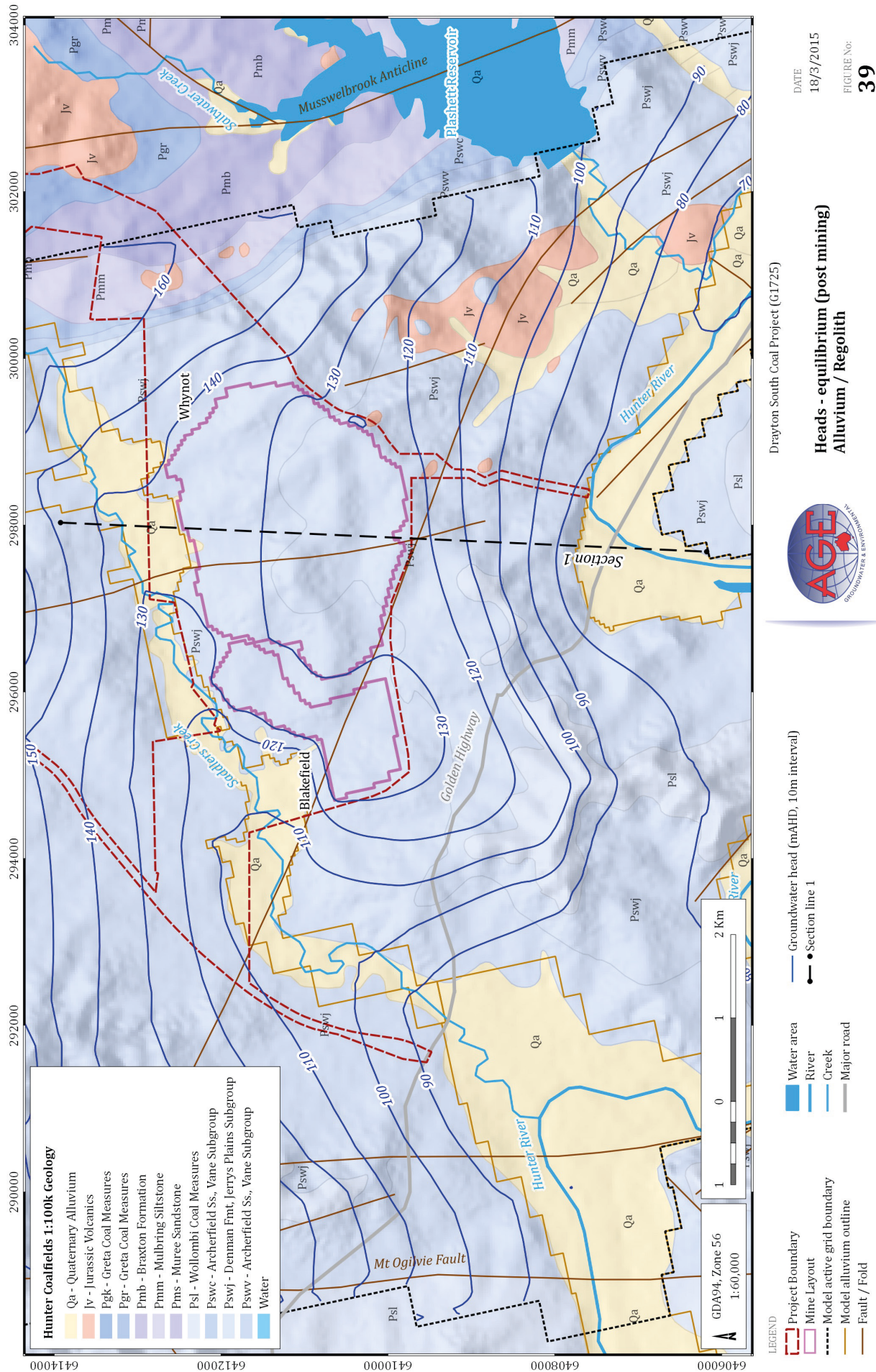
The contours shown on Figure 39 and Figure 40 illustrate that the head within the spoil attains an elevation of 128 mAHD. The contours also suggest the Whynot void will act as a “window” into the water table of the saturated spoil.

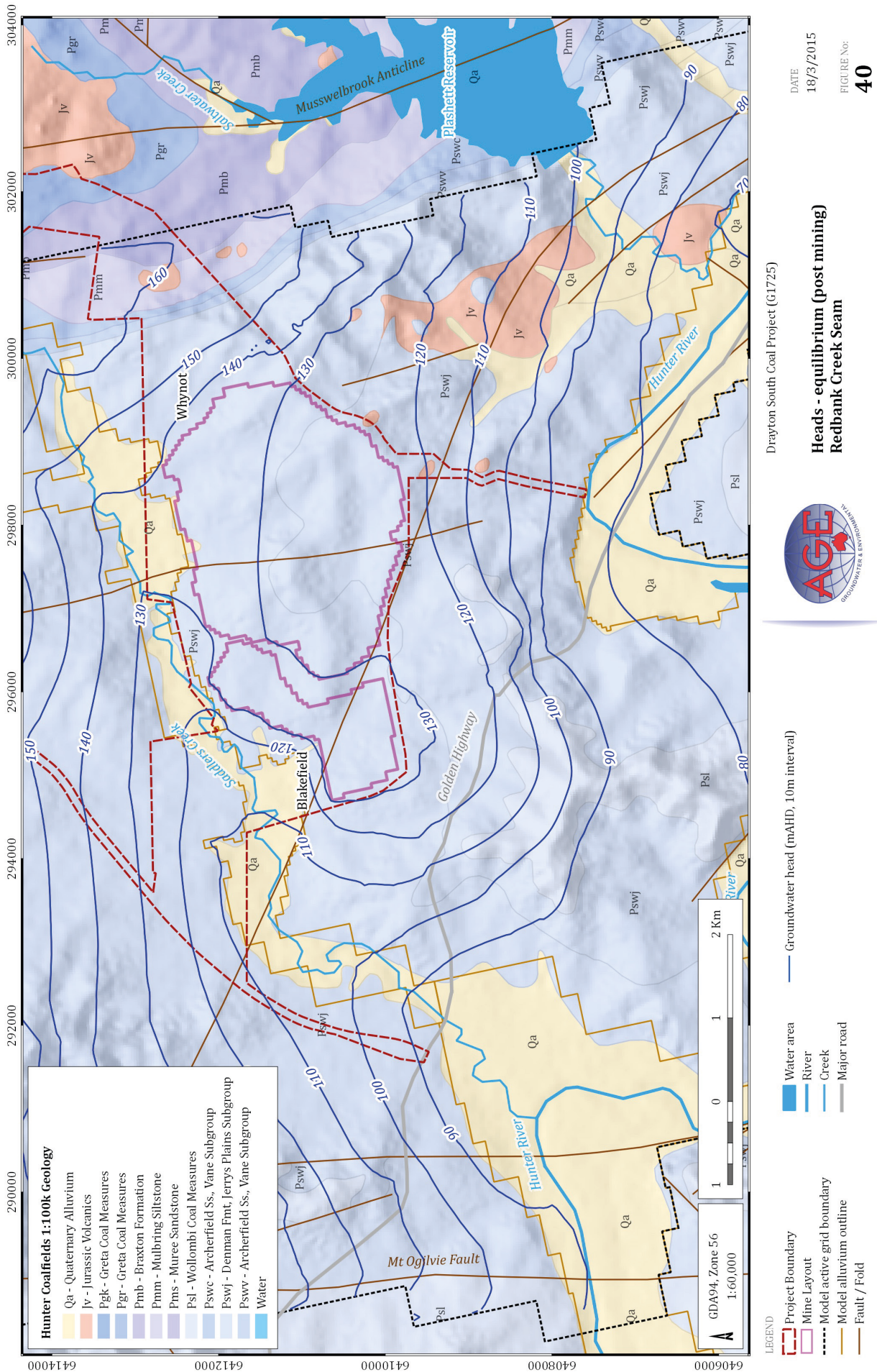
13.4 Predicted impact on groundwater users

No registered bores are located within the predicted zone of drawdown influence at equilibrium (post mining) as shown in Figure 37 and Figure 38. The two bores located within the Whynot mining area (both owned by Anglo American) will be removed by mining.









13.5 Movement of water away from mining areas

The contours shown in Figure 39 suggest the spoil areas and the void will collectively act as a “flow through system”, which is recharged from the north-east and discharged towards the north-west, west, south-west, and south. The predicted hydraulic gradients suggest seepage from the spoil area is likely to migrate beyond the mining area and into the surrounding Permian coal measures. A portion of this water is predicted to ultimately migrate into the Saddlers Creek alluvium and the Hunter River alluvium. Water that originated from spoil will initially mix with water in the Permian coal measures and then with water in the alluvium systems before any of it discharges into the surface water systems.

13.5.1 Movement of water away from Whynot mining area

Figure 41 shows the predicted hydraulic gradient established at equilibrium between the Whynot mining area spoil and the surrounding geological units, including the Permian coal measures, Saddlers Creek alluvium and the Hunter River alluvium.

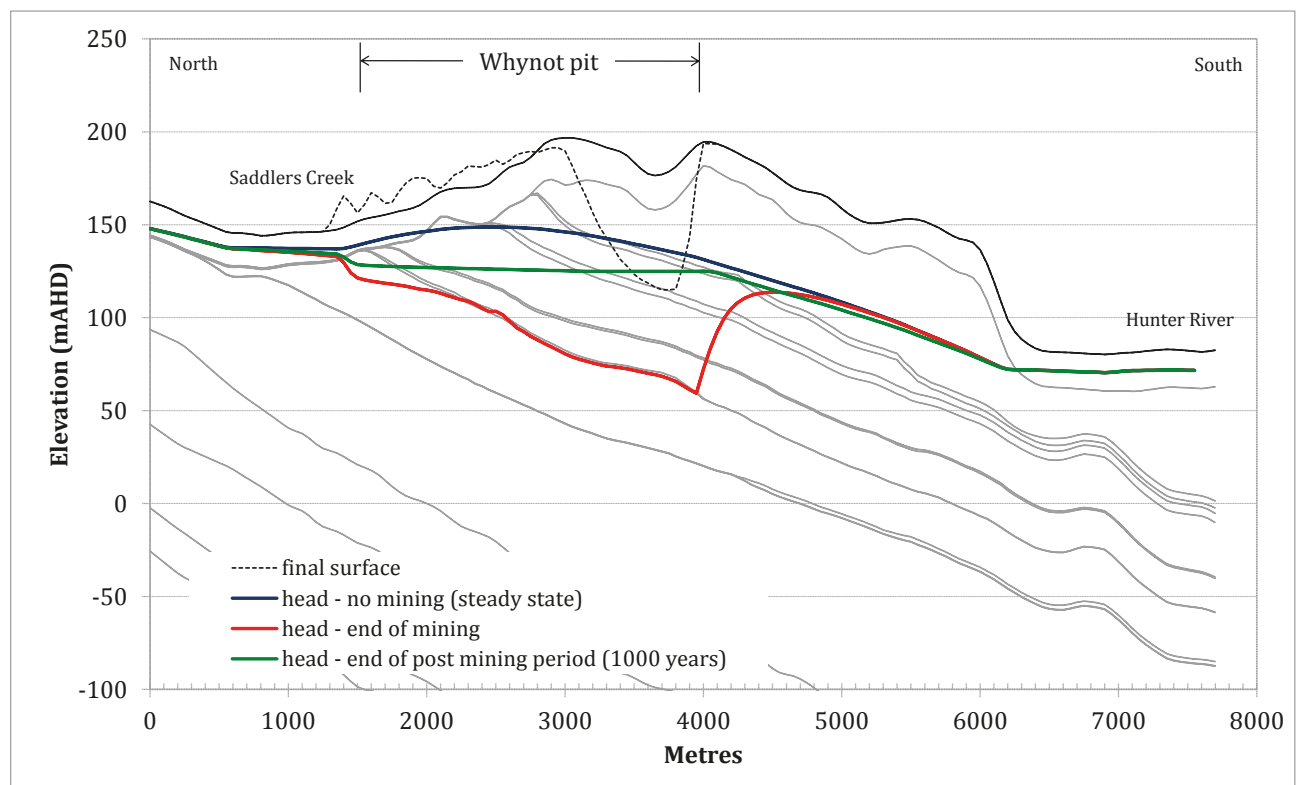


Figure 41 Cross-section of head elevation – Section 1

The hydraulic gradient adjacent to the Whynot mining area will be maintained away from Saddlers Creek. Spoil water is predicted to predominantly migrate towards the south, following the hydraulic gradient (Figure 39).

The gross groundwater flow from the surrounding geology (i.e. Permian coal measures) into the Whynot spoil is predicted to decline over time as the water level within the spoil recovers post mining. The gross groundwater flow into the Whynot spoil is predicted to decrease from 142 ML/year to 31 ML/year, over 800 years post mining (Figure 42).

Conversely, the gross flow of spoil water into the surrounding geology is predicted to increase over time as the water level within the spoil recovers. The gross groundwater flow from the Whynot spoil is predicted to increase from 0 ML/year up to 6 ML/year (Figure 42). No movement of water from the spoil is predicted to occur for the first 30 years after mining.

Overall, the post mining net movement of groundwater is towards the Whynot spoil area. The net movement of water into the spoil decreases from 142 ML/year down to 25 ML/year (Figure 42).

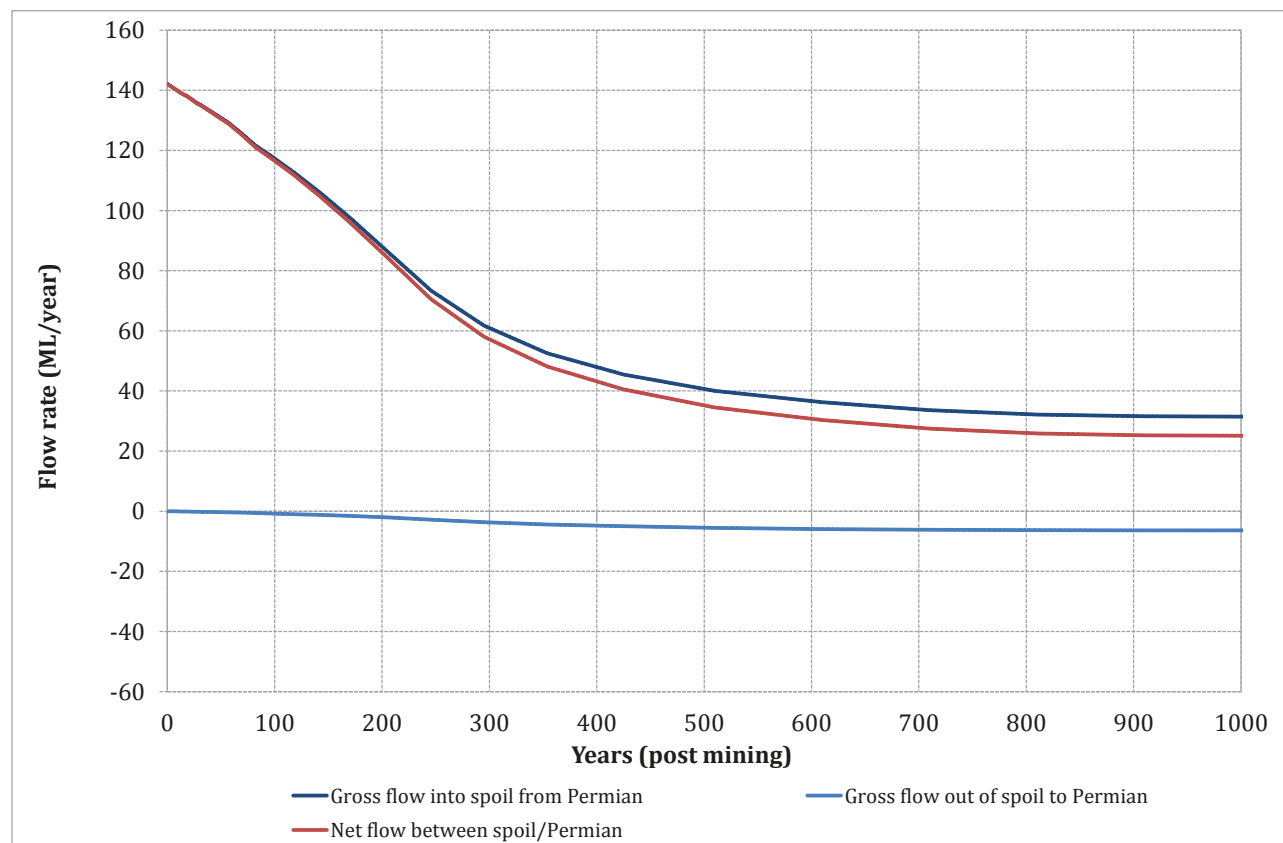


Figure 42 Water budget for Whynot spoil area

13.5.2 Movement of water away from Blakefield mining area

The Blakefield mining area will be completely backfilled and rehabilitated. The final landform will not contain a void area. Therefore, water level recovery within the spoil will not be influenced by evaporative processes that are associated with void areas.

In the long-term, a hydraulic gradient will be established towards Saddlers Creek, away from the Blakefield mining area. Spoil water is predicted to migrate predominantly towards the north and west, following the hydraulic gradient (Figure 39).

Similar to the Whynot spoil, the gross groundwater flow from the surrounding geology (i.e. Permian coal measures) into the Blakefield spoil is predicted to decline over time as the water level within the spoil recovers after mining ceases. The gross groundwater flow into the Blakefield spoil is predicted to decrease from 67 ML/year to 1 ML/year, over 245 years post mining (Figure 43).

The gross flow of spoil water into the surrounding geology is predicted to increase over time as the water level within the spoil recovers. The gross groundwater flow from the Blakefield spoil is predicted to increase from 1 ML/year up to 39 ML/year (Figure 43).

Overall, the net movement of water is towards the Blakefield spoil area from the surrounding geology for the first 80 years after mining. After 80 years, the hydraulic gradient is such that the net movement of water is away from the spoil, increasing from 0 ML/year up to 39 ML/year (Figure 43).

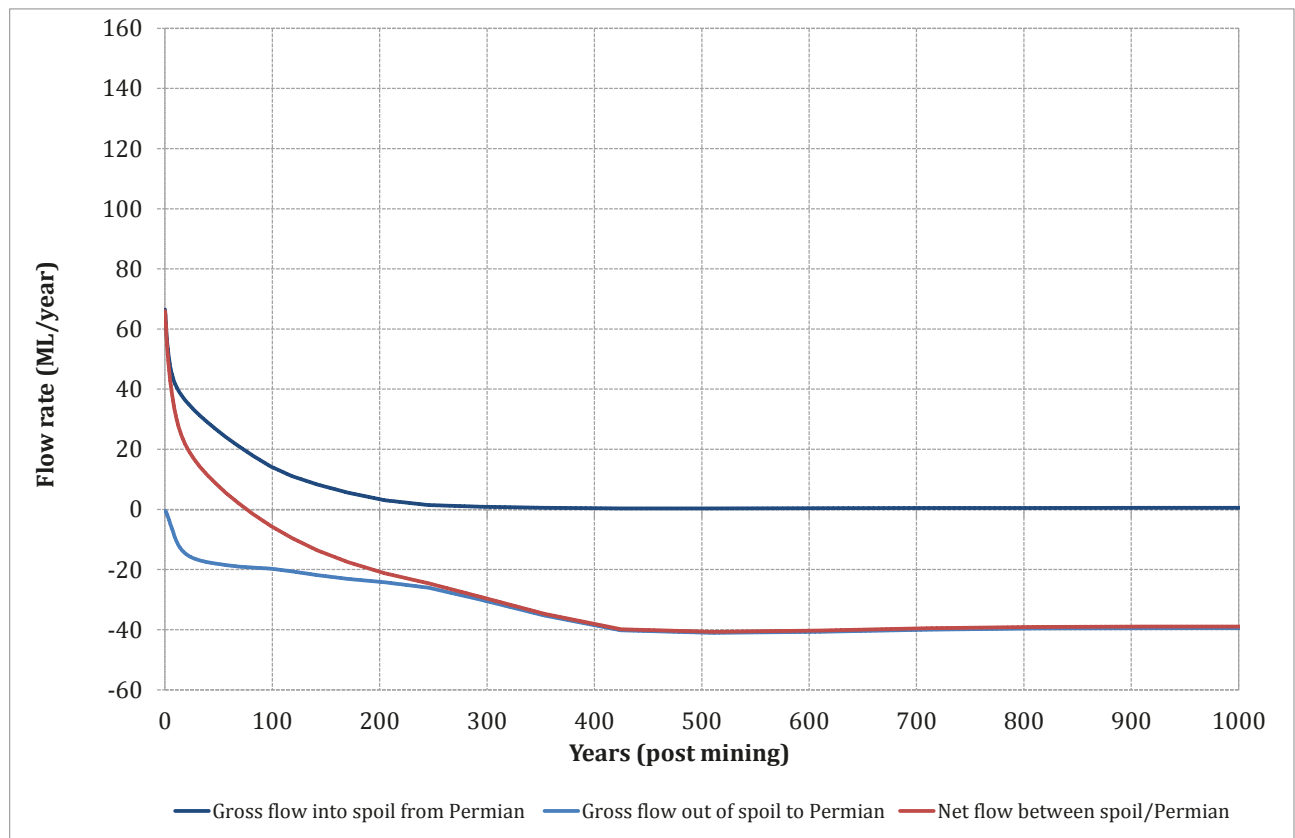


Figure 43 Water budget for Blakefield spoil area

13.6 Predicted impact on alluvial water budgets and baseflow

13.6.1 Leakage to Saddlers Creek alluvium

As previously discussed in Section 12.4.1, the hydraulic gradient is predicted to reverse away from the Saddlers Creek alluvium soon after mining ceases (Figure 33). The reversed hydraulic gradient will cause water to migrate away from the alluvium into the underlying Permian coal measures.

The hydraulic gradient is predicted to remain reversed for about 140 years post mining. After this time, the hydraulic gradient is predicted to return towards the Saddlers Creek alluvium as groundwater levels recover in the adjacent mining areas. The maximum impact is predicted to occur about 30 years post mining (Figure 33).

After the hydraulic gradient has returned towards the Saddlers Creek alluvium (after 140 years post mining), the rate of upward leakage from the Permian coal measures into the Saddlers Creek alluvium is predicted to steadily increase in response to an increasing hydraulic gradient away from the saturated Blakefield mining area spoil. The results presented in Table 19 show the rate of upward leakage from the Permian coal measures into the Saddlers Creek alluvium is predicted to progressively increase (recover) to about 98 ML/year, which is 5 ML/year lower than the original rate prior to mining.

Table 19 Predicted Permian leakage to Saddlers Creek alluvium – post mining

Year after mining	Leakage from Permian to Saddlers Creek alluvium (ML/year)	Maximum change (i.e. loss) (ML/year)
Pre-Mining	103 (towards alluvium)	-
0 - 30	9 - -31 (towards Permian)	94 - 134
30 - 140	-31 - 0	134 - 103
140 - 400	0 - 82	103 - 20
400 - 800	82 - 97	20 - 6
800 - equilibrium	97 - 98	6 - 5

13.6.2 Baseflow to Saddlers Creek

Baseflow to Saddlers Creek from the alluvium is predicted to occur during and after mining, but at a reduced rate. As previously discussed in Section 12.4.2, baseflow to Saddlers Creek from the alluvium is predicted to be progressively reduced by up to 76 ML/year by the end of mining.

However, the maximum decline in baseflow is predicted to occur about 50 years post mining (Figure 34). The maximum change in baseflow to Saddlers Creek is predicted to be 130 ML/year. The results presented in Table 20 show the rate of baseflow to Saddlers Creek from the alluvium is predicted to progressively increase (recover) to the long-term rate of about 240 ML/year, which is 5 ML/year lower than the original rate prior to mining.

Table 20 Predicted baseflow to Saddlers Creek – post mining

Year after mining	Baseflow from alluvium to Saddlers Creek (ML/year)	Maximum change (i.e. loss) (ML/year)
Pre-Mining	245	-
1 - 50	245 - 115	0 - 130
50 - 300	115 - 198	130 - 47
300 - 500	198 - 231	47 - 14
500 - 800	231 - 239	14 - 7
800 - equilibrium	239 - 240	7 - 5

13.6.3 Leakage to Hunter River alluvium

Leakage to the Hunter River alluvium from the Permian coal measures is predicted to remain unchanged during mining, and initially post mining. However, the rate of upward leakage into the alluvium is predicted to be slightly reduced from about six years after mining ceases.

The results presented in Figure 33 show the rate of upward leakage from the Permian into the Hunter River alluvium is predicted to progressively reduce, between six and 245 years after mining. Table 21 shows the maximum predicted change in leakage rate to the alluvium is about 8 ML/year.

After 245 years post mining, the rate of upward leakage from the Permian into the Hunter River alluvium is predicted to steadily increase. The results presented in Table 21 show the rate of upward leakage into the alluvium is predicted to progressively increase (recover) to about 89 ML/year, which is 2 ML/year lower than the original rate prior to mining.

Table 21 Predicted Permian leakage to Hunter River alluvium – post mining

Year after mining	Leakage from Permian to Hunter River alluvium (ML/year)	Maximum change (i.e. loss) (ML/year)
Pre-Mining	91	-
0 - 6	91 - 91	0
6 - 245	91 - 83	0 - 8
245 - 500	83 - 86	8 - 5
500 - 800	86 - 89	6 - 2
800 - equilibrium	89 - 89	2 - 2

13.6.4 Base flow to Hunter River

Baseflow to the Hunter River from the alluvium is predicted to occur during and after mining. The baseflow is predicted to not be impacted during mining, as previously discussed in Section 12.4.4.

The rate of baseflow to the Hunter River alluvium is predicted to be reduced soon after mining ceases as a new hydraulic gradient is established towards the river system. The results presented in Figure 34 show the rate of baseflow from the alluvium into the Hunter River is predicted to progressively reduce for the first 300 years post mining. Table 22 shows the maximum predicted change in baseflow to the Hunter River is about 10 ML/year.

After 350 years post mining, the rate of baseflow into the Hunter River is predicted to steadily increase (recover). The results presented in Table 22 show the rate of baseflow into the Hunter River is predicted to progressively recover to about 800 ML/year, which is 3 ML/year lower than the original rate prior to mining.

Table 22 Predicted baseflow to Hunter River – Post mining

Year after mining	Baseflow from alluvium to Hunter River (ML/year)	Maximum change (i.e. loss) (ML/year)
Pre-Mining	803	-
0 - 300	803 - 793	0 - 10
300 - 500	793 - 798	0 - 5
500 - 900	798 - 800	5 - 3
900 - equilibrium	800 - 800	3 - 3

13.7 Predicted water quality within the spoil areas and Whynot void

13.7.1 Review of background information for spoil pore water salinity

The mineralogy and chemical processes occurring within the saturated zone of an overburden emplacement area have been reviewed in detail for several coal mining operations in the Upper Hunter Valley of NSW by Mackie (2009).

Using XRD analyses of interburden core samples, Mackie (2009) demonstrated a common mineral regime dominated by quartz with subordinate albite, kaolinite, illite-smectite, and dolomite. Batch reaction trials on a range of these core samples (representing different overburden/interburden lithologies) indicated leachates exhibiting $\text{Na} > \text{Mg} > \text{Ca}$ and $\text{HCO}_3 > \text{Cl} > \text{SO}_4$ ionic species distributions.

Mackie (2009) carried out batch reaction trials on 58 rock cores from a number of locations and depths throughout the Upper Hunter Valley. The trials involved the submergence of rock samples in de-ionised water, whilst pH and salinity (EC and TDS) were regularly recorded between two to eight months. The procedure is considered to replicate the “bath tub effect” where spoils are emplaced in a mine pit shell and progressively re-saturated with rainwater. The batch reaction trials assumed negligible contribution from groundwater and also assumed no mass transfers into or out of the mine pit other than CO_2 .

Salinity within the batch reaction trials was observed by Mackie (2009) to “*rise rapidly during the first days of saturations and thereafter at a reducing rate towards long term equilibration*”. The measured salinity trends during the trials were extrapolated to 100 years assuming equilibrium would occur during that time. Appendix F summarises the results from the batch trials.

The batch reaction trials show that salinity levels of overburden pore water were observed to increase significantly during initial saturation and thereafter increased more slowly towards a long-term equilibrium value. Long-term pore water TDS concentrations (projected out to 100 years) ranged between 500 mg/L and 5000 mg/L, with an average of 2150 mg/L. These projections compare to an average measured value of 600 mg/L after 70 days of saturation.

13.7.2 Spoil and void water salinity

The spoil water TDS concentration has been calculated using the results of the Mackie (2009) batch reaction trials. The salinity of water stored within the Whynot and Blakefield mining area spoil was predicted by calculating the TDS concentration of the mixture between groundwater seepage from surrounding Permian coal measures and spoil pore water (accumulated through rainfall recharge).

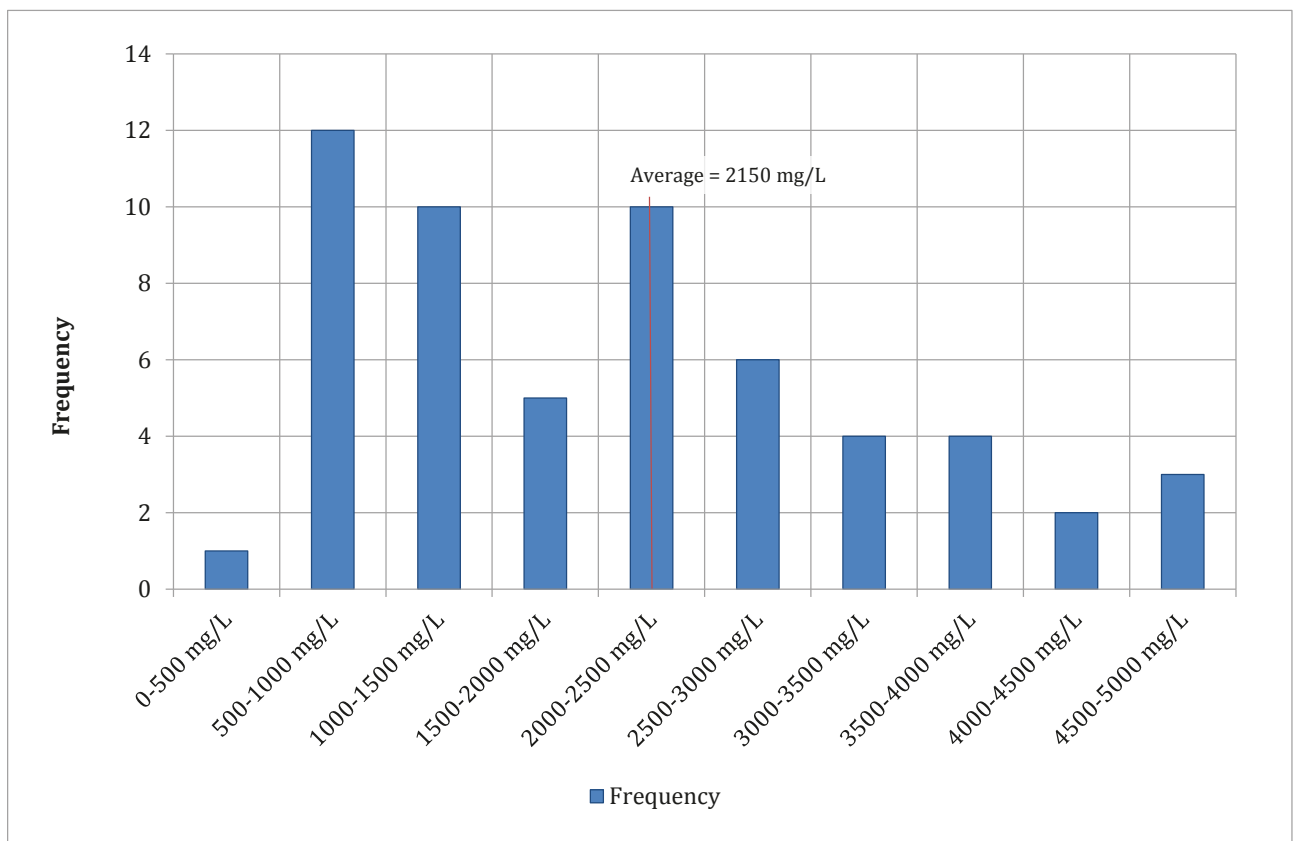
13.7.2.1 Spoil water salinity – Whynot mining area

The gross rate of seepage from the Permian coal measures into the spoil of the Whynot mining area was predicted to reduce from an initial gross rate of 142 ML/year, down to an equilibrium gross rate of 31 ML/year. The TDS concentration of groundwater from the Permian coal measures was assumed to be a constant 3500 mg/L, which is the average concentration of Permian coal measure groundwater.

The rate of deep percolation through the spoil profile was predicted to be about 347 ML/year, which is likely to remain constant over time assuming average rainfall conditions. Saturation of the spoil was predicted to take about 245 years after mining, after which a lake is predicted to develop in the void area. During the first 245 years, deep percolation of rainfall through the spoil will result in a significant volume of spoil that is saturated (i.e. spoil pore water).

The TDS concentration of deep percolation of rainfall was assumed to be a constant 2150 mg/L, which is considered conservative because:

- the projected (100 year) data provided by Mackie (2009) shows that it is positively skewed (Figure 44), meaning that there were a greater number of values in the Mackie (2009) dataset that were less than the average TDS concentration of 2150 mg/L; and
- the approach assumes that the spoil is instantaneously filled with rainwater that has infiltrated from the surface. This water reacts with the spoil material in a trend similar to that projected by Mackie (2009).



Source: Mackie, 2009

Figure 44 Distribution of projected long-term salinity data (after Mackie, 2009)

The TDS concentration of the mixture between spoil pore water and groundwater inflow to the spoil was calculated to be initially 2542 mg/L, which then decreased to 2262 mg/L over time (Figure 45). These results assume complete mixing occurs between the two different water sources.

The assumption that mixing is complete provides a worst case scenario. In reality, complete mixing of water within the spoil profile is not likely to occur, as fresher (less dense) rainfall recharge water is likely to stratify above more saline (more dense) groundwater seepage. The stratification is likely to lead to preferential seepage of fresher water from the spoil into the Whynot void area and surrounding geological units.

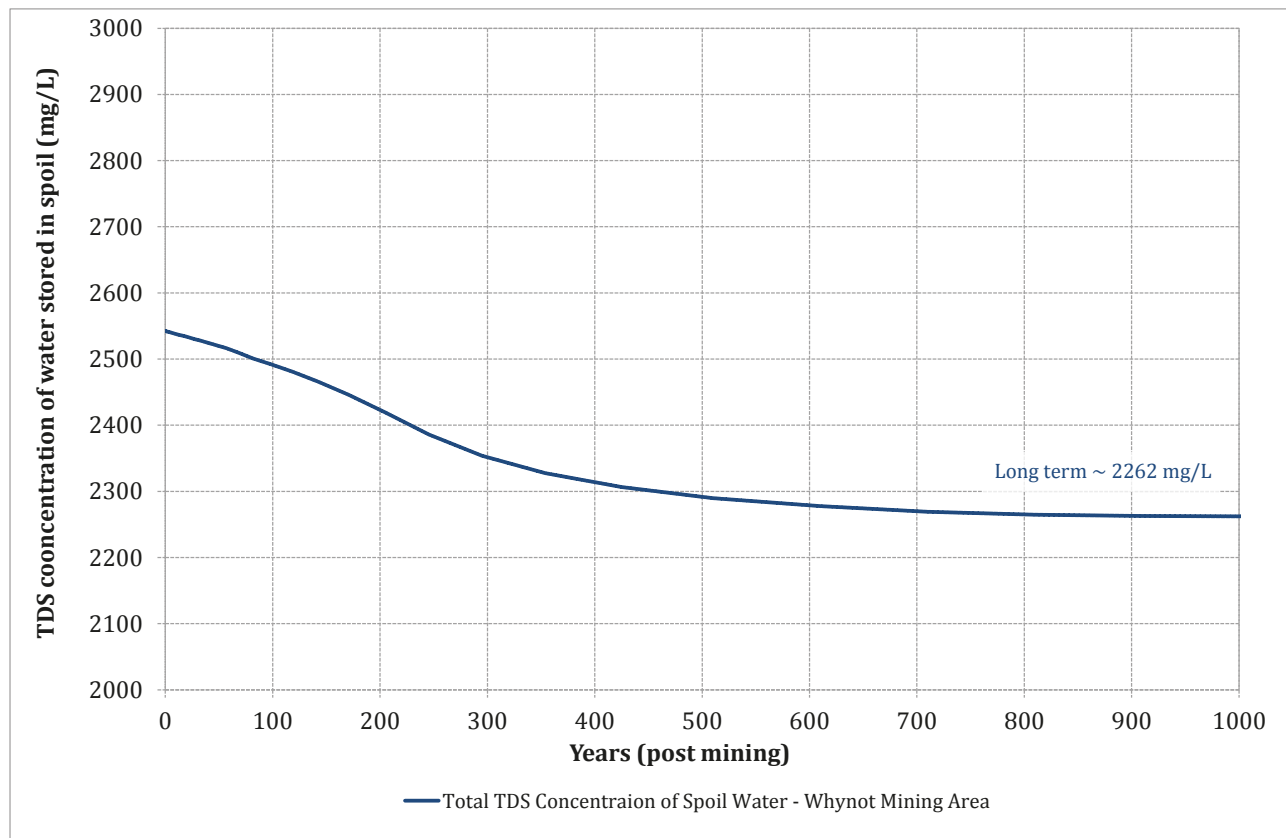


Figure 45 Calculated TDS concentration of spoil water – Whynot mining area

Whilst the TDS concentration of Whynot spoil is predicted to be about 2262 mg/L, this concentration has been calculated assuming that no mixing occurs between the spoil water and the void lake (after one is formed about 245 years after mining). The hydraulic gradients in the long-term will result in a “flow through” system within the spoil and the void. The gradients will enable gross flow of water from the void into the spoil of about 100 ML/year. Salts that have accumulated in the void through evaporative processes will be transported into the spoil as a result of the water migration.

The transported salts will initially dilute and mix within the spoil water. However, over considerable time (i.e. moving towards equilibrium) the spoil water will become increasingly more saline because of the additional salt sourced from the void. A highly conservative assumption would be that the void derived salts pervasively mix through the spoil, and this process will ultimately result in the spoil attaining a TDS concentration comparable with the void.

13.7.2.2 Whynot void water salinity

The long-term build-up of TDS in the Whynot void was assessed by an OPSIM surface water balance model which was configured to replicate the void behavior (WRM, 2015). The OPSIM model adopted a historical rainfall data sequence from 1889 to 2010, which was repeated for 1000 years after mining. The predicted TDS concentration in the final void is shown in Figure 46.

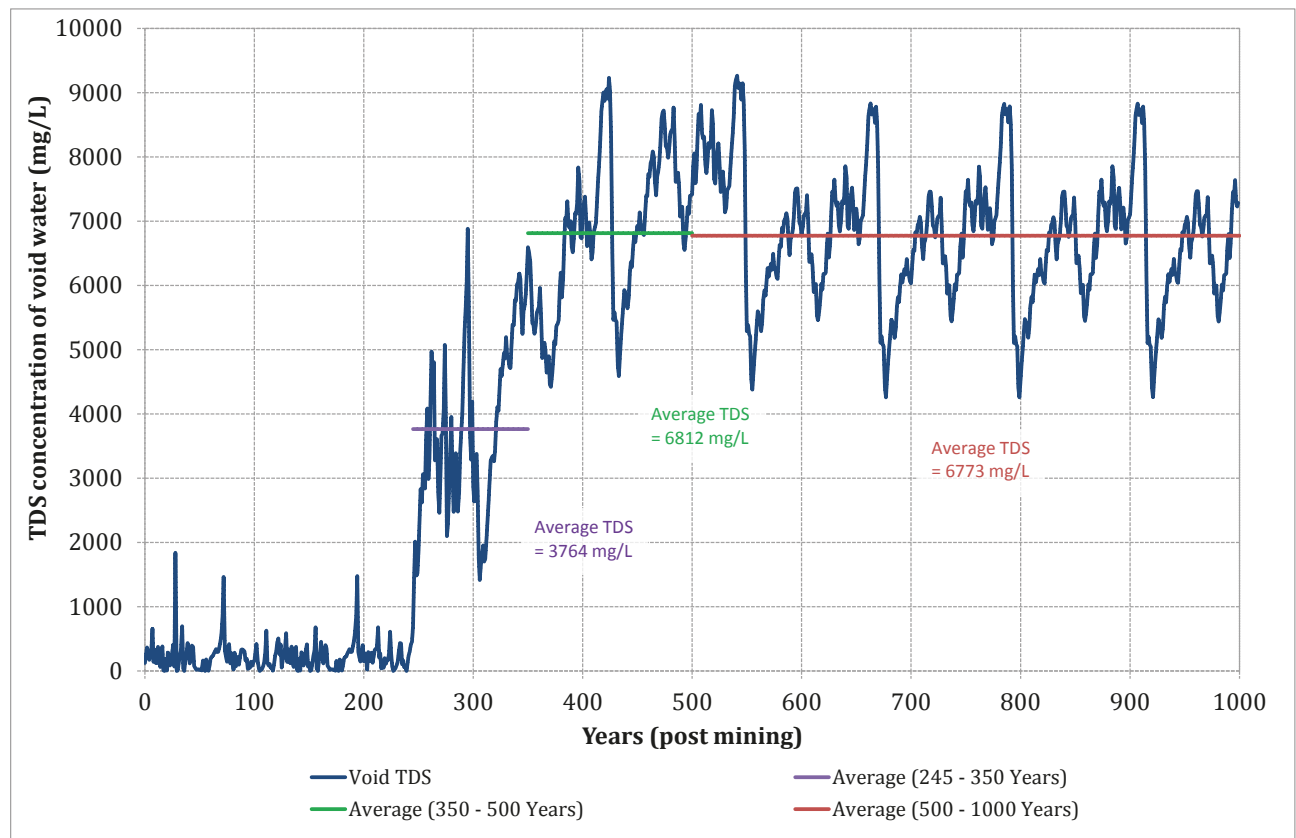


Figure 46 Calculated TDS concentration of water stored within the void

The salinity in the final void will not begin to increase until the spoil is sufficiently saturated to enable water to seep into the void from the surrounding spoil. This process is anticipated to commence after about 245 years post-mining.

The modelling concluded that the void water will have an average TDS concentration of:

- 3764 mg/L for the period between 245 and 350 years post mining. This concentration of TDS is marginally higher than surrounding Permian coal measure groundwater which has an average TDS of about 3500 mg/L.
- 6812 mg/L for the period between 350 and 500 years post mining. The elevated TDS of void water is caused by evaporative effects.
- 6773 mg/L for the period between 500 and 1000 years post mining (i.e. equilibrium).

As stated in the previous section, a highly conservative assumption would be that the void derived salts pervasively mix through the spoil, and this process will ultimately result in the spoil attaining a TDS concentration comparable with the void.

13.7.2.3 Spoil water salinity – Blakefield mining area

The same methods used to predict the salinity of water within the Whynot spoil were also applied to predict the salinity of water in the Blakefield spoil.

The gross rate of seepage from the Permian coal measures into the spoil of the Blakefield mining area was predicted to reduce from an initial gross rate of 67 ML/year, down to an equilibrium gross rate of 1 ML/year. The TDS concentration of groundwater from the Permian coal measures was assumed to be a constant 3500 mg/L.

The rate of deep percolation through the spoil profile was predicted to be about 56 ML/year, which is likely to remain constant over time assuming average rainfall conditions. The TDS concentration of deep percolation of rainfall was assumed to be a constant 2150 mg/L (Mackie, 2009).

The TDS concentration of the mixture between spoil pore water and groundwater inflow to the spoil was calculated to be initially 2881 mg/L, which then decreased to 2162 mg/L over time (Figure 47). These results assume complete mixing occurs between the two different water sources.

The Blakefield mining area will be completely backfilled and rehabilitated. The final landform will not contain a void area. Therefore, TDS concentration within the spoil will not be influenced by evaporative processes that are associated with void areas.

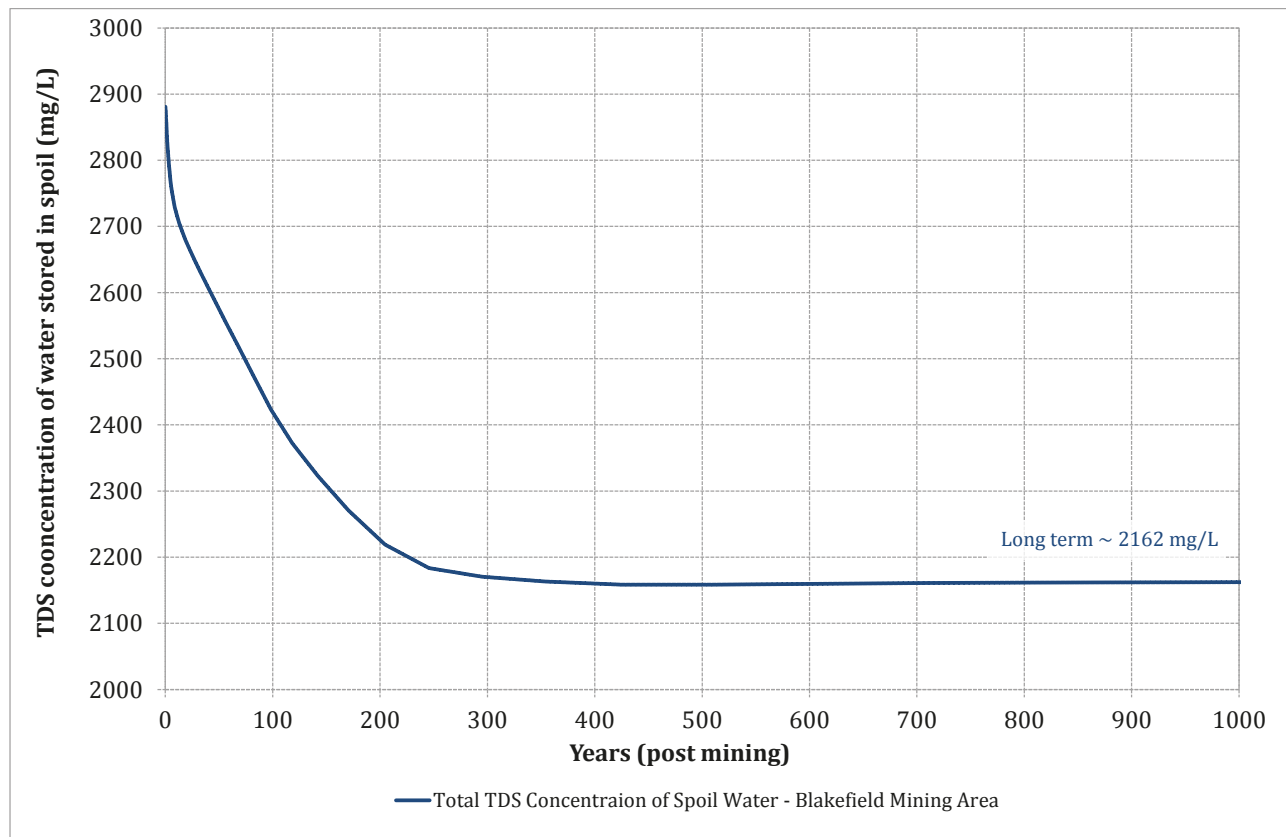


Figure 47 Calculated TDS concentration of spoil water – Blakefield mining area

13.8 Predicted impact on groundwater quality

13.8.1 Saddlers Creek alluvium

The existing beneficial use of the Saddlers Creek alluvial groundwater will not be impacted post mining. The Saddlers Creek alluvium will likely remain too saline for primary industries in the long-term.

Conversely, the groundwater quality within the Saddlers Creek alluvium may be improved after mining due to reduced upward leakage from the Permian coal measures, which is the main source of natural salinity in the alluvium.

The results presented in Table 19 show the very long-term rate of upward leakage from the Permian coal measures into the Saddlers Creek alluvium is predicted to be about 98 ML/year, which is 5 ML/year lower than the original rate prior to mining. The Permian coal measures have an average TDS concentration of about 3500 mg/L.

A proportion of the long-term leakage into the Saddlers Creek alluvium is predicted to be sourced from the Blakefield spoil area. The gross flow of spoil water from the Blakefield mining area into the surrounding geology is predicted to increase up to a maximum of 39 ML/year (Figure 43). However, not all of this water will be received into the Saddlers Creek alluvium, as it will first mix with water in the Permian coal measures that immediately surround the mining area.

The predicted long-term TDS concentration of spoil water within the Blakefield mining area (2182 mg/L – Section 13.7.2.3) will be lower than the pre-mining average TDS concentration of the Saddlers Creek alluvium (~6000 mg/l). Therefore, migration of lower TDS spoil water into the Saddlers Creek alluvium may reduce the salinity of water in the alluvium over the long-term.

The long-term major ion chemistry of spoil water in the Blakefield mining area is expected to be broadly consistent with observed groundwater qualities in the region, but with generally lower TDS.

The Saddlers Creek alluvium will continue to receive low TDS recharge from rainfall unaffected by mining.

13.8.2 Hunter River alluvium

The existing water quality attributes required for beneficial use of the Hunter River alluvium will not be impacted post mining. The beneficial use will remain suitable for primary industry with the main potential use being for stock watering, and limited irrigation where better water quality water is present.

The results presented in Table 21 show the maximum reduction of upward leakage from the Permian coal measures into the Hunter River alluvium is predicted to about 10 ML/year, compared to the rate prior to mining. The reduced rate of upward leakage may lead to improved alluvial water quality post mining. However, this change is highly unlikely to be measureable as the very small reduction in upward leakage will be buffered by the dominant recharge processes (river leakage and rainfall).

A hydraulic gradient will eventually be established away from the Whynot mining area, towards the Hunter River, as water levels recover within the spoil and void area (Figure 39 and Figure 41). The hydraulic gradient will cause water to migrate away from the Whynot spoil/void into the surrounding Permian coal measures. Eventually, a proportion of the long-term Permian leakage into the Hunter River alluvium is predicted to be sourced from the Whynot spoil/void.

As spoil/void seepage water migrates through the adjacent groundwater regime, the water will initially mix with groundwater stored within the Permian coal measures, then with groundwater stored within the Hunter River alluvium, prior to baseflow discharge to the Hunter River.

The gross flow of spoil/void water from the Whynot mining area into the surrounding geology is predicted to increase over time to a maximum rate of 6 ML/year (Figure 42). For the first 350 years after mining, the TDS concentration of the spoil/void seepage water is predicted to be comparable to water in the Permian coal measures. There will obviously be no salinity increase within either the Permian coal measures or the Hunter river alluvium during first 350 years post mining.

After 350 years post mining, the TDS concentration of water within the Whynot spoil/void is predicted to be higher than water within the surrounding Permian coal measures. A highly conservative assumption would be that the water within the Permian coal measures located directly down-gradient of the spoil/void would ultimately attain a TDS concentration comparable with the spoil/void water. This would mean that a portion of the Permian leakage to the Hunter River alluvium will eventually have a higher TDS concentration compared to pre-mining conditions.

The processes that control the transport of salt from the Whynot spoil/void, through the Permian coal measures to the Hunter River alluvium are complex. Hence, calculations representing these processes are not straightforward. Many assumptions are required and the timescale over which the assumptions are applied is long. Notwithstanding this, simplified mixing calculations (chemical mass balance equations) using conservative assumptions can be applied to assess the magnitude of the potential impact on water quality within the Hunter River alluvium.

A set of highly conservative assumptions were applied to assess a 'worst-case' scenario. Specifically, the TDS concentration of the spoil/void seepage from the Whynot mining area was assumed to be equal to the predicted average TDS concentration of void water. The TDS concentration of Permian seepage into the Hunter River alluvium was therefore assumed to be:

- 3764 mg/L for the period between 245 – 350 years;
- 6812 mg/L for the period between 350 – 500 years; and
- 6773 mg/L for the period between 500 – 1000 years.

These TDS concentrations are likely to be highly conservative because they are based on the assumption that spoil/void seepage from the Whynot mining area and water in the Permian coal measures (immediately down-gradient) will both attain equivalent TDS concentrations.

Table 23 summarises the flow rates and TDS concentrations used to undertake the mixing calculations within the Hunter River alluvium. The 'worst case' mixing calculations indicate the long-term average TDS concentration of the Hunter River alluvium is predicted to:

- not be increased by seepage water for at least the first 350 years post-mining;
- increase by 9 mg/L (~1.6 %) between 350 and 500 years post mining; and
- increase by 25 mg/L (~4.3 %) between 500 and 1000 years post mining.

Even when based on this highly conservative worst case mixing scenario there is only predicted to be a slight increase in TDS concentrations within the Hunter River alluvium adjacent to the Project and it will not lower the beneficial use category of the alluvium, thus satisfying the AIP minimal impact considerations.

Table 23 TDS mixing calculations of bedrock leakage to Hunter River alluvium

Process	Flow rate (ML/year)	TDS concentration (mg/L)	Salt (kg/year)	Total salt (kg/year)	Total flow rate (ML/year)	Mixed TDS concentration (mg/L)	Percent change of TDS concentration from pre- mining
Pre-mining							
Rainfall recharge into aquifer	690 [^]	10	6899	454024	818	555	-
Seepage from Permian	128 [^]	3500 [*]	447125				
245 – 350 years post mining							
Rainfall recharge into aquifer	690	10	6899				
Seepage from Permian	119	3500	416465	442598	814	544	-2.12%
Seepage from mining area	5 [^]	3764 ⁺	19234				
350 – 500 years post mining							
Rainfall recharge into aquifer	690	10	6899				
Seepage from Permian	119	3500	415188	459382	814	564	1.61%
Seepage from mining area	5	6812	37296				
500 – 1000 years post mining							
Rainfall recharge into aquifer	690	10	6899				
Seepage from Permian	122	3500	425408	474332	818	580	4.28%
Seepage from mining area	6	6773	42026				

Note: [^] sourced from groundwater model^{*} sourced from average groundwater chemistry data (AGE, 2012)⁺ sourced from averaged void water TDS concentrations (WRM, 2015)

13.8.3 Permian coal measures

The beneficial use of the Permian coal measures will not be impacted post mining for at least 350 years. The beneficial use will remain suitable for primary industry with the main potential use being for stock watering.

After 350 years, the Permian coal measures immediately down-gradient of the Whynot mining area may progressively be impacted by increasing salinity (TDS) caused by seepage from the mining area. All other areas of the Permian coal measures (i.e. up-gradient) will not be impacted.

As discussed in Section 13.8.2, a highly conservative assumption is that the water within the Permian coal measures located directly down-gradient of the spoil/void would attain a similar TDS concentration compared with water in the spoil/void. This assumption infers the TDS concentration of the Permian coal measures down gradient of the mining area may increase from its current average concentration of 3500 mg/L, up to 6812 mg/L (350 years to 500 years post mining) and 6773 mg/L (500 years to 1000 years post mining) (Figure 46). At these TDS concentrations, the water in Permian coal measures will not be suitable for stock watering.

There are currently no registered bores located immediately down-gradient from the proposed mining area and the land is owned by Anglo American. The absence of registered bores generally throughout the Permian coal measures signals the limited supply and poor water quality that this rock formation often produces.

13.9 Predicted impact on reliable water sources (Hunter River) quality

The Hunter River meets the criteria for “reliable surface water” because it flows for greater than 95% of time and has an average TDS of less than 1500 mg/L.

The minimal impact considerations of the AIP require “*no increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity*”. This means that the Project is required to demonstrate that its operation during mining, and post-mining, will not increase the long-term average salinity of Hunter River by more than 1%.

An assessment of predicted changes in surface water quality for Saddlers Creek are not required by the AIP (refer to Section 9.3).

13.9.1 Existing water quality of the Hunter River

The AIP does not specify the long-term average salinity of the Hunter River, nor does the policy specify the river flow conditions from which to calculate the long-term average salinity.

Water quality data is available for the Hunter River at the Glennies Creek gauging station (Station No. 210127). The data recorded by this station is used in the calculation of the Hunter River Salinity Trading Scheme (HRSTS) discharges and is likely to be indicative of Hunter River salinity adjacent to Project. The Glennies Creek gauging station is located some 30 km downstream of the study area.

The average flow in the Hunter River at the Glennies Creek station has been 85775 ML/year (235 ML/day) since recording began in 1993. The average TDS concentration of the Hunter River at the Glennies Creek station during 50th percentile flows is 550 mg/L.

Figure 48 shows the relationship between stream flow and TDS at the Glennies Creek station. The logarithmic trend line for flows is also shown and demonstrates a strong relationship between flow rate and TDS, with high flows (i.e. floods) having lower TDS concentrations. Higher TDS concentrations occur when there are limited releases from Glenbawn Dam and the majority of flow is being generated from the downstream catchments.

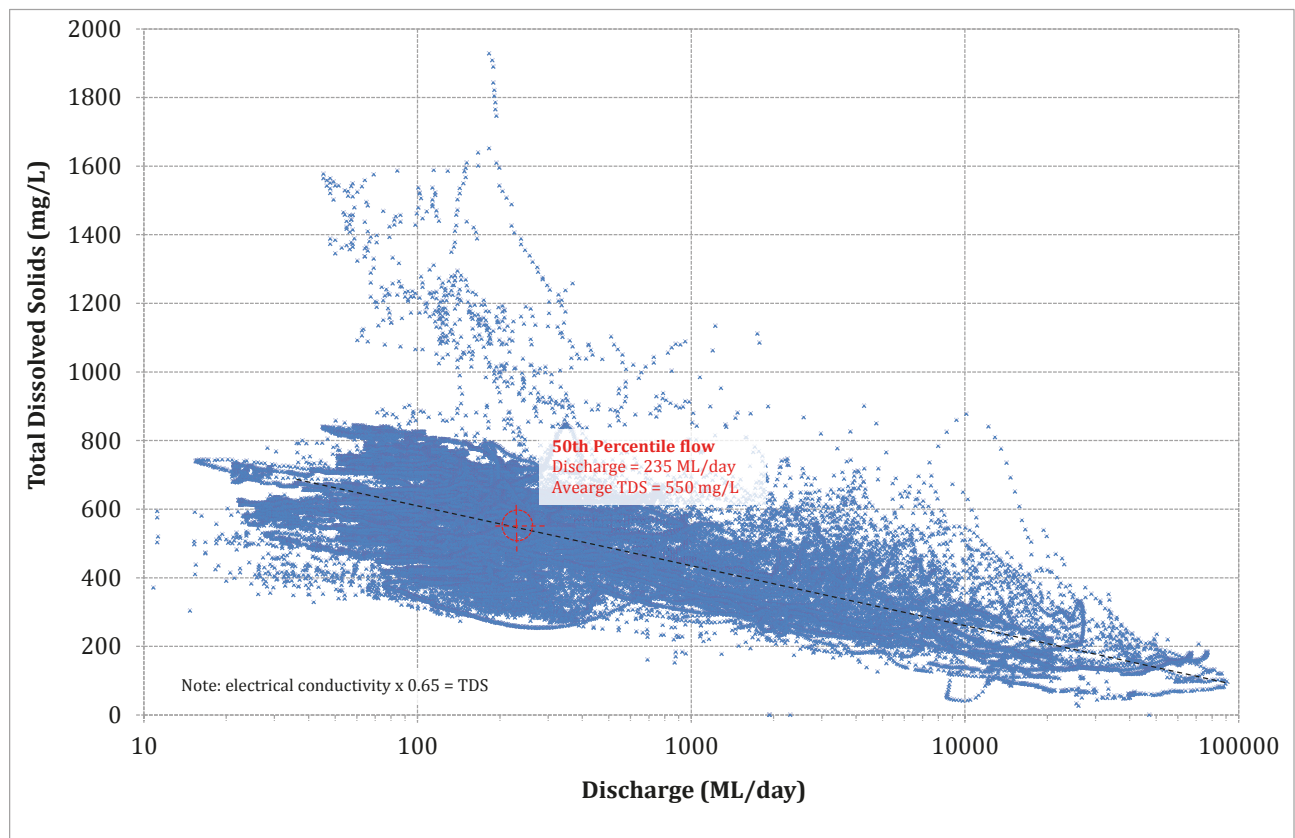


Figure 48 Stream Flow and TDS Relationship for the Hunter River at Glennies Creek

Although the average flow within the Hunter River is 235 ML/day, the HRSTS defines the river to be in a state of “low flow” when the rate of flow is less than 1800 ML/day for the reach above the Glennies Creek station. According to this classification, the Hunter River is most commonly in a state of “low flow”.

The HRSTS was introduced by the NSW Government to reduce salinity levels in the Hunter River and allows controlled water discharges into the Hunter River during periods of high flow. The HRSTS operates under the *Protection of the Environment Operations (Hunter River Salinity Trading Scheme) Regulation 2002*.

Under the HRSTS, credit holders are permitted to discharge saline water to the Hunter River on a managed basis. The aim is to maintain river salinity levels below 600 $\mu\text{S}/\text{cm}$ (390 mg/L TDS) at Denman and 900 $\mu\text{S}/\text{cm}$ (585 mg/L TDS) at Singleton.

The AIP requires the long-term average salinity of the Hunter River not to increase by more than 1%, which equals 555 mg/L during average “low flow” conditions. From a practical point of view, the allowable increase of TDS concentration is considered to be very low, and unlikely to be differentiated from natural variability and precision of measuring instruments. In effect, the AIP requires no detectable change to TDS concentrations.

13.9.2 Predicted impact on Hunter River water quality

The average TDS concentration of the Hunter River is not predicted to increase by more than 1 % as a result of the Project.

Groundwater baseflow to the Hunter River from its connected alluvium is predicted to continue during and after mining, albeit at a very slightly reduced rate (Figure 48). Natural baseflow to the Hunter River contributes salts to the Hunter River. The groundwater model estimates pre-mining baseflow to the Hunter River contributes about 445 tonnes/year of salt to the system along the length of the modelled river section.

In comparison, the salt load transported downstream by the river (pre-mining) is about 47176 tonnes/year (Figure 48), which is over two orders of magnitude greater than the estimated salt load contributed by the alluvium. Therefore, any potential future increase in the TDS concentration of the alluvium will be significantly buffered by the dominant salt load contributed by the Hunter River.

The TDS concentrations predicted for the Hunter River alluvium (Table 28) were mixed with average flow and TDS concentrations of the Hunter River (Table 24). These mixing calculations indicate the long-term average TDS concentration of the Hunter River is predicted to:

- not be increased by the Project for at least the first 350 years post-mining;
- increase by 0.02% between 350 and 500 years post mining; and
- increase by 0.04 % between 500 and 1000 years post mining.

Table 24 TDS mixing calculations of baseflow to the Hunter River

Process	Flow rate (ML/year)	TDS concentration (mg/L)	Salt (kg) / year	Total salt (mg) / year	Total flow rate (ML/year)	Mixed TDS concentration (mg/L)	Percent change of TDS concentration from pre-mining
Pre-mining							
Average flow within river	85775 *	550 †	47176250	47622166	86578	550.0	-
Aquifer baseflow to river (net gain)	803 ^	555 *	445916				
245 – 350 years post mining							
Average flow within river	85775	550	47176250	47608527	86570	549.9	-0.02%
Aquifer baseflow to river (net gain)	795	544	432277				
350 – 500 years post mining							
Average flow within river	85775	550	47176250	47626568	86573	550.1	0.02%
Aquifer baseflow to river (net gain)	798	564	450318				
500 – 1000 years post mining							
Average flow within river	85775	550	47176250	47640418	86575	550.3	0.04%
Aquifer baseflow to river (net gain)	800	580	464168				

Note: * sourced from mixing calculation in Table 23.

+ sourced from NOW, 2014 – See Figure 4

^ sourced from groundwater model

† sourced from <http://realtime.data.water.nsw.gov.au/water.stm>

14. Sensitivity analysis

A sensitivity analysis was undertaken to demonstrate the response of the model to variations in uncertain input parameters. The objective of the sensitivity analysis was to rank the input parameters in terms of their influence on the predicted results. The key parameters with the highest uncertainty and those most likely to affect the magnitude of the predictions are hydraulic conductivity, rainfall recharge rates, and aquifer storage. Some parameter groupings were varied by 1 order of magnitude (hydraulic conductivity and specific storage), while the others were only changed by half an order of magnitude as a full order of magnitude change would be outside of reasonable parameter values. The following perturbations were assessed in the sensitivity analysis:

- A ± 1 Order of magnitude (10M) change in the horizontal and vertical hydraulic conductivity values for all model layers;
- A $\pm 50\%$ change in the rainfall recharge rate across the model domain;
- A $\pm 10\text{M}$ change in the specific storage for all model layers; and
- A $\pm 50\%$ change in the specific yield for all model layers.

14.1 Sensitivity analysis of seepage rates to mine pits

Figure 49 and Table 25 summarise the sensitivity of the predicted seepage rates to the mine pits in response to changed model parameters. Seepage rates to the mining areas were most sensitive to changes in hydraulic conductivity, specific storage, recharge, and specific yield in decreasing order of influence, although it should be noted that some were varied by an order of magnitude, while others were only varied by half an order of magnitude.

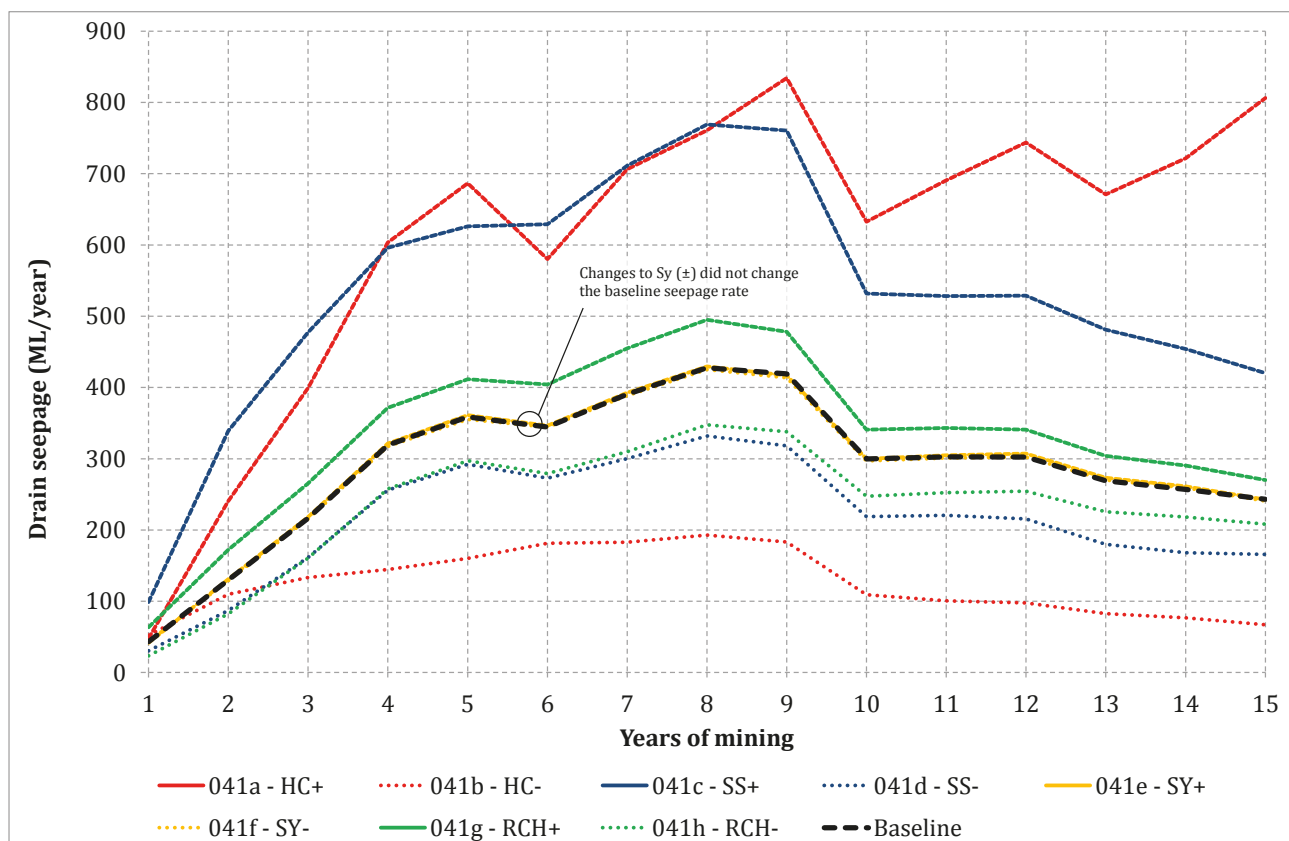


Figure 49 Total seepage to mine pits – sensitivity

Table 25 Sensitivity analysis output - seepage

Year	Seepage (ML/year)								
	Baseline	Hydraulic conductivity (Kh & Kv)		Specific storage (Ss)		Specific yield (Sy)		Recharge	
	Baseline	+10M	-10M	+10M	-10M	+50 %	-50 %	+50 %	-50 %
1	43	48	52	99	30	42	43	63	23
2	130	241	110	339	87	131	129	172	82
3	217	399	133	477	161	218	216	265	160
4	319	603	144	596	256	321	317	372	258
5	359	687	160	626	292	361	355	412	297
6	345	580	181	629	273	346	344	404	279
7	391	706	183	711	300	393	389	455	310
8	427	761	193	769	332	430	425	495	348
9	419	834	183	761	318	417	414	478	338
10	300	633	109	532	219	300	297	341	247
11	303	691	101	528	221	305	301	343	252
12	302	744	98	529	216	307	302	341	254
13	269	671	83	481	180	273	270	304	226
14	257	722	77	454	168	261	259	290	218
15	243	806	67	420	166	243	241	270	208
average	288	608	125	530	215	290	287	334	233
Max.	427	834	193	769	332	430	425	495	348

The changes for hydraulic conductivity and specific storage have the greatest impact on the level of calibration.

Table 26 indicates that the model becomes significantly de-calibrated during the sensitivity scenarios.

Table 26 Sensitivity analysis output - calibration

Measure		Baseline	Hydraulic conductivity		Specific storage (Ss)		Specific yield (Sy)		Recharge	
			(Kh & Kv)							
	Unit	Baseline	+10M	-10M	+10M	-10M	+50%	-50%	+50%	-50%
<i>steady state</i>										
sum of residuals (SR):	[m]	863	2056	3512	n/a	n/a	n/a	n/a	1154	1168
root mean square (RMS):	[m]	13.20	27.61	43.80	n/a	n/a	n/a	n/a	15.62	16.79
scaled RMS (SRMS):	[%]	7.55	15.78	25.04	n/a	n/a	n/a	n/a	8.93	9.60
<i>transient</i>										
sum of residuals (SR):	[m]	56340	121737	155073	56588	55685	56344	56336	54749	76901
root mean square (RMS):	[m]	18.08	32.59	43.21	18.13	17.90	18.08	18.07	17.56	22.47
scaled RMS (SRMS):	[%]	14.21	25.62	33.96	14.25	14.07	14.21	14.21	13.80	17.66

14.2 Groundwater drawdown

The sensitivity of the predicted zone of depressurisation was also assessed. Figure 50 to Figure 53 present drawdown contours for Layer 1. The drawdown contours were most sensitive to recharge, hydraulic conductivity, and storage, in decreasing order. None of the sensitivity simulations produced a 1 m drawdown contour that extended into the Hunter River alluvium.