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ELIWANA MINING PROJECT

GROUNDWATER IMPACT ASSESSMENT

Submitted to:
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REPORT



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1.0 INTRODUCTION

This report has been prepared for Fortescue Metals Group Ltd (Fortescue) by Golder Associates Pty Ltd (Golder) in response to a Request for Proposal (RFP) by Fortescue for hydrogeological services to carry out a dewatering and near mine water supply assessment for Stage 1 of the proposed Eliwana Mining Project (the Project).

This report presents the results of a groundwater impact assessment carried out for proposed mine dewatering and water supply across the Project area (Figure 1). The groundwater impact assessment is part of a phased study approach for the project. Supporting information and context for the work presented in this report is contained within the following reports:

- Hydrogeological Conceptual Model Report (1671484-002-R)
- Groundwater Model Development and Calibration Report (1671484-003-R)
- Mine Dewatering and Water Supply Modelling Report (1671484-004-R)

Details of the Project, proposed mining activities and geological/hydrogeological studies have been summarised here in this report where necessary to support the results/outcomes of the impact assessment.

2.0 BACKGROUND

2.1 Project Background

Fortescue is assessing the potential development of a new iron ore mining area located approximately 140 km west of their existing Solomon Mine. The Project lies on the northern limb of the east west trending Brockman Syncline. It comprises multiple ore bodies within both the bedded Brockman Iron and Marra Mamba Iron Formation rock types.

Below water table mining is proposed in both the Brockman Iron Formation and Marra Mamba Iron Formation pits which will require dewatering. Other activities associated with the mining proposal that may impact water resources of the area include land form changes encompassing pits and waste rock dumps, diversion and or capture of creek flows, water supply pumping and management of surplus water.

2.2 Summary of Hydrogeological Investigations

A hydrogeological program of work was initiated in mid-2016 by Fortescue to collect data including regional geological mapping and literature review, exploration drill hole data, assay results and exploration water supply monitoring data/information, which was used to develop a conceptual geological model for the mining area. This model was used to plan further hydrogeological drilling studies which comprised the drilling of 10 production bores and 11 monitoring bores, followed by a program of test pumping, single well ("slug") testing and downhole geophysical surveying. Subsequently, automated data loggers have been placed down hole in monitoring bores to build up a pre mining temporal data set on groundwater levels.

The above information has been used by Golder to develop and document a conceptual hydrogeological model (Golder, 2017a) upon which a numerical groundwater model (Golder, 2017b) was constructed and reviewed by Fortescue. Fortescue provided Golder with a mine plan and life of mine water demand estimate in annual increments to apply within the groundwater model for an assessment of the proposed mine site water balance and potential extent of groundwater level drawdown (Golder, 2017c).

The numerical model was then coupled with individual mine pit analytical models to understand key parameters driving closure outcomes and potential impacts with which to support government environmental approvals for mining.

2.3 Topography and Climate

Regionally, the Project is located within the Duck Creek catchment of the Ashburton River Drainage Basin. Drainage lines extend downhill and through valleys into the Boolgeeda and Pinarra Creeks (Figure 1). The Boolgeeda Creek flows westward from Mount Brockman, whereas the Pinarra Creek (a small drainage



system) drains south into the Boolgeeda. The Boolgeeda Creek eventually flows into Duck Creek some 23km downstream from its convergence with Pinarra Creek (MWH, 2011).

The Project is situated within the headwaters of mainly local catchment drainages that feed into the main systems described above. Local drainage is shown in Figures 2A-2C. A catchment divide is located in close proximity to the proposed eastern most Brockman Iron Formation deposit, where tributaries of the Boolgeeda Creek flow south east and the Pinarra Creek drains to the west (Figure 2B). The tributaries that flow south and east into Boolgeeda Creek generally cover the eastern part of the Project (termed the “Flying Fish” area), and have an upper catchment provenance that includes rock types of the Fortescue Group (see Section 6.1). The west flowing Pinarra Creek has a provenance of mainly Hamersley Group sediments and is associated with the western part of the Project (termed the “Eliwana” area).

Surface runoff from hillslope catchments comprise fast flowing, fresh (water quality) run-off with a short response time. At present, there are no known pools or springs in the Project area (MWH, 2011).

According to the Köppen climate classification system the Pilbara Region has a dry arid to semi-arid climate, with two distinct seasons; hot summers with seasonal periodic rainfall and high evaporation rates and warm winters. Climate statistics from the Bureau of Meteorology for Site number 5005 – Hamersley, located 46.8 km north northwest of Tom Price, and approximately 50 km northeast of Flying Fish, indicate mean annual rainfall of 385.4 mm (1912-2015). Bureau of Meteorology generated local gridded rainfall data was reviewed and presented similar rainfall data at Eliwana and Flying Fish as the Hamersley site. The Bureau of Meteorology website (www.bom.gov.au) indicates Class A pan evaporation is around 3,200 mm/annum, which is an order of magnitude greater than annual rainfall.

2.4 Geology

The basement geology of the Brockman Syncline comprises the three Groups from the Mount Bruce Supergroup; namely the Fortescue, Hamersley and Turee Groups. These groups are arranged in a large syncline structure with a broadly east-west axis. Eliwana lies on the northern limb of the syncline and as such all the bedded stratigraphy dips to the south at between 30-45°, with the oldest bedded metasediments to the north, progressing through overlying younger metasediments to the south towards the centre of the syncline. A detailed description of the geology and nomenclature adopted can be found in MacLeod and de la Hunty (1966). A summary of constituent geology Groups, Formations and Members is provided in Golder (2017a)

2.5 Hydrogeology

2.5.1 Groundwater Occurrence

Groundwater occurs within both fractured rock aquifers of the Archean-Proterozoic basement; and surficial Paleogene-Neogene sediments where the water table is located near to the surface along dissected creeks and within gorges. There are three main aquifers for consideration with respect to dewatering and water supply planning as detailed below:

- The **Wittenoom Aquifer** found within the Bee George, Paraburdoo and West Angela Members of the Wittenoom Formation and comprising dolomite, banded iron and minor chert. Where saturated, the Cainozoic sediments and detrital materials overlying the Wittenoom Formation bedrock have been considered part of the Wittenoom Aquifer for simplicity;
- The mineralised **Marra Mamba Aquifer** found within the upper mineralised Mount Newman Member of the Marra Mamba Formation; and
- The mineralised **Brockman Aquifer** characterised by enrichment of the parent banded iron formation within the mineralised Brockman Iron Formation members; that is, the ore body. Within this environment, groundwater replaces the silicate and carbonate gangue minerals with goethite, resulting in an aquifer with higher porosity and permeability.

The conceptualisation of the Project area is that the Wittenoom Formation and Mount Newman Member form a single, continuous aquifer. The differentiation in nomenclature was chosen herein to highlight that each



hydro-stratigraphic unit within the groundwater model can be parametrised on an individual basis. This feature of the groundwater model allows the simulation of groundwater abstraction for water supply to be targeted to the geological members which make up the aquifer rather than grouping these features into a single, broad aquifer designation.

There are three main aquitards that compartmentalise the Project's groundwater system: the Mount McRae Shale between the Brockman Aquifer and the Wittenoom Aquifer; the lower Marra Mamba and Fortescue Group to the north of the Project; and the un-mineralised Brockman Iron Formation and Weeli Wolli Formation to the south. Furthermore the basement rocks are criss-crossed with NW-SE trending and NE-SW trending dolerite dykes. Whilst water table differences are only marginal between the aquifers and aquitards, there are significant differences in head along strike of the valley either side of the dolerite dykes, in places the difference is 10's of metres.

As a consequence of the above, the Project area has been divided up into a series of groundwater sub-catchments. The identification of the sub-catchments was based on groundwater levels inferred from down hole resistivity surveys of mineral exploration holes across the project area. For the most part, measured groundwater levels indicate very flat hydraulic gradients, separated by large level changes either side of NW-SE trending lineaments mapped as dolerite dykes where basement rocks outcrop to the north or south of the valley.

Eleven sub catchments were inferred by their approximate head elevation in relative metres above Australian Height Datum (Table 1). The locations of each of the groundwater sub-catchments and potential groundwater dependant ecosystems (GDE's) are shown in Figures 2A to 2D. The highest groundwater (level) elevation is in the east at 570 m AHD and the lowest is in the west at 393 m AHD. The distribution of these sub catchments is shown in Figure 4 (long section through the valley floor). The compartmentalisation of the groundwater sub catchments has been demonstrated on the basis of test pumping responses in certain areas (Golder 2017a). Other areas could be defined by future testing pumping and larger scale pumping of the aquifer (dewatering) which will allow a more definitive statement on the extent and distribution of groundwater sub catchments.

Table 1: Groundwater sub-catchments

Groundwater Catchment	Sub-	Pit Name or Area Name	Aquifer
572		Flying Fish	Wittenoom
570		Flying Fish	Wittenoom
545		Flying Fish	Wittenoom
553		Flying Fish	Wittenoom
544		NA	Wittenoom
497		NA	Wittenoom
500		MM4-6	Wittenoom
517-519		NA	Wittenoom
510		Eagles Nest	Wittenoom
502		NA	Wittenoom
474		Talisman	Wittenoom
459		Broadway East	Wittenoom
457		Westend	Mineralised
454		Westend J6	Mineralised
393		Broadway West	Wittenoom

2.5.2 Groundwater Balance

As a consequence of the hydrogeological setting where there is low permeability aquitards to the north (Lower Marra Mamba Iron Formation and Fortescue Group), to the south (Yandicoogina Shale Member,



dolerite sill and Weeli Wolli Formation) and dolerite dykes cross cutting the general east-west strike length, groundwater through flow is thought to be very low. This hypothesis is supported by the large variation in head either side of the dolerite dykes. As such groundwater through flow is relatively insignificant in comparison to groundwater storage (Golder 2017a). Groundwater stored within each sub catchment was calculated given a range of estimated specific yields and assumptions about aquifer depth based on hydrogeological drilling results.

The sub-catchments can receive rainfall-recharge via surface water infiltration along the valley where creek lines coincide with shallow depths to the groundwater table. As surface water run-off occurs only after significant rainfall events, it follows that recharge occurs only after significant events and is of a rapid nature with little chance for evaporation of surface water. The calibrated recharge applied to the groundwater model was 3 mm per annum (<1% of mean annual rainfall) and this recharge was only applied across the low lying areas along the valley (Wittenoom Formation) and the mineralised zones.

Discharge of groundwater on a sub catchment level may occur either through internal transfer through the dolerite dykes (very minor) or through evapotranspiration from GDE's. The amount of recharge and discharge is expected to be insignificant in comparison with total groundwater storage within each groundwater sub catchment.

Given the dykes appear to compartmentalise water levels either side of a structure, and that within individual sub catchments hydraulic gradients appear negligible, a water balance for each individual sub catchment, in terms of through flow, could not be resolved (Golder 2017a). However water balances were resolved for those catchments where groundwater dependent vegetation was mapped and losses from the groundwater via evapotranspiration could be estimated. The estimated storage volumes and catchment water balances are presented in Golder (2017a).

2.5.3 Groundwater Quality

Groundwater chemistry data (major ions and physical parameters) have been collected from 15 monitoring and production bores across the Project area. The major ions were plotted on a piper trilinear diagram in Golder (2017a) to understand the hydro-chemical facies present. The piper diagram plots indicate that groundwater in the west (Eliwana) is of magnesium bicarbonate type, whereas groundwater in the west (Flying Fish) was of a mixed type bordering on chloride anion dominant groundwater. Overall the alkaline earth metals (Mg, Ca) are more dominant than sodium potassium alkalis. The high alkalinity results in laboratory pH in all groundwater analysed to be above 7.8. Flying Fish groundwater was clearly more brackish than Eliwana groundwater, being generally greater than 1200mg/L up to 1700mg/L TDS. Eliwana groundwater was generally fresh, although still above Australian Drinking Water Guidelines (ADWG) for human consumption for aesthetics (taste) at between 500 to 800mg/L TDS. Groundwater at Flying Fish also exceeds ADWG for health for Boron in every bore sampled; groundwater at Eliwana production bores were at (or exceeded) the recommended guideline limit for health for Boron in most instances.

3.0 PROPOSED MINE WATER MANAGEMENT ACTIVITIES

3.1 Mine Plan

The preliminary mine plan provides nominal locations of pit shells, waste rock dumps, adjoining access corridors and the minimum bench RL for each proposed mine pit. The pit crest outlines of each proposed mine pit are shown in Figures 3A – 3D. This geographic information has been used to plan where dewatering or water supply bores can be reasonably located, given knowledge of aquifer extent and location.

The minimum mine bench RL was compared against the conceptual groundwater level to calculate the maximum pre-mining saturated thickness for each pit. Seven below water table (BWT) pits have been identified in this preliminary mine plan. Of these pits, three comprise 26m or less of maximum saturated thickness (intersected groundwater depth). Of the remaining four BWT pits, the most significant dewatering effort will be required at Westend (147m saturated thickness), Talisman 2 (49m saturated thickness) and MM4-6 (50m of saturated thickness).



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A summary of the mine plan for the dewatering assessment are provided in Table 2. As indicated in Section 4.1.1, a conservative impact assessment approach has been adopted to account for future changes to this preliminary mine plan; both in terms of pit location, pit depth and scheduling.

Table 2: Eliwana Mining Project preliminary mine plan dewatering summary

Pit Name	Pre Mining SWL (m RL)	Minimum Bench (m RL)	Saturated thickness (m)	Pit Start date	BWT intersected date	Approximate Start of dewatering ¹
BROADWAY EAST	459	435	24	1 Mar 2020	1 Mar 2023	1 Mar-2022
BROADWAY WEST	393	363	30	1 Dec 2026	1 Dec 2028	1 Dec 2027
EAGLES_NEST	510	492	18	1 Jun 2024	1 Dec 2031	1 Dec 2030
MM4-6	500	450	50	1 Dec 2032	1 Dec 2033	1 Dec 2032
TALISMAN 2	475	426	49	1 Dec 2020	1 Dec 2022	1 Dec 2021
WESTEND	457	310	147	1 Mar 2020	1 Dec 2029	1 Dec 2026
WESTSIDE	474	456	19	1 Jun 2021	1 Sep 2024	1 Sep 2023

3.2 Mine Dewatering

The mine dewatering approach has been determined from industry standard practices. The actual methodology will be assessed at the site level as Operations get closer to commencement and the ultimate mine plan sequence is resolved. Potential dewatering volumes were investigated based on a nominal mine plan and vertical advance rate using the numerical groundwater model. Sensitivities related to key parameters such as hydraulic conductivity and specific yield were assessed to consider potential outcomes. Individual bore yields were estimated based on the results of the hydrogeological drilling campaign to resolve bore numbers and rationalise schedule.

Groundwater points of abstraction will vary depending on the type of ore body being mined. It is assumed that below water table Brockman Iron Formation pits will require in pit dewatering bores, whilst below water table Marra Mamba Iron Formation pits could be dewatered from in pit bores, or down dip ex pit bores, or a combination of both. Alternative dewatering methods, such as directional drilling, may also be considered.

3.3 Mine Water Demand

Water is required for dust suppression, dry processing facilities and mine camp / potable supply throughout the mine life. A wet processing water demand commences from 2024. Early mine construction water demand is required at start-up (2019/20) and for the construction of the proposed wet process plant in 2023 / 24. As such, water demand comprises annual variations and ranges from a minimum of 4GL/a up to a peak of 6.2GL/a in 2024 and 2025. Figure A presents the annual demand in graphical format with a comparison of the different demand sources.

At this preliminary stage, no allowance has been made for daily variation in demand and the supply demand simulated represents an average daily demand based on the estimated annual cumulative demand provided by Fortescue.

¹ Time has been estimated assuming the final date of in pit mining is based on whether the next period in the plan represented a quarterly or annual step, however better definition of mine plan dates would be preferable. Where the plan instantaneously commences a pit BWT; pre dewatering at a rate of 25m per annum is assumed.



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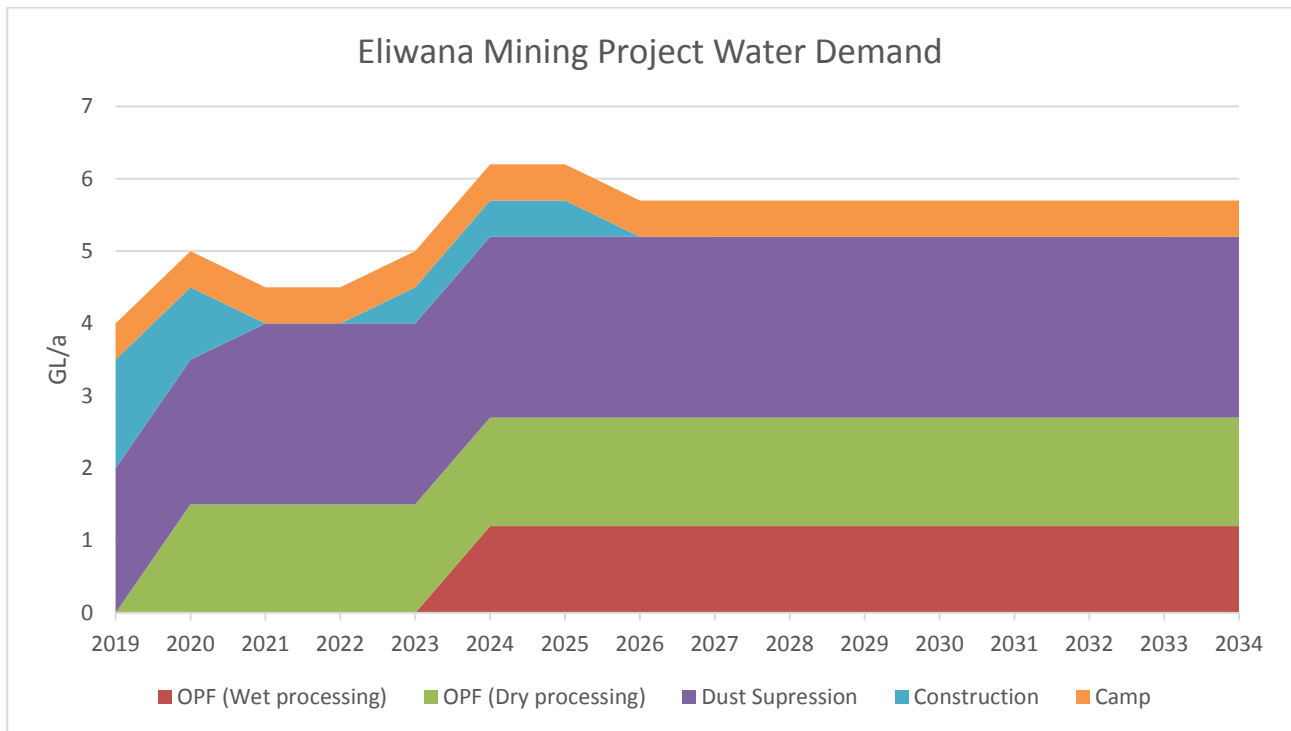


Figure A: Estimated annual water demand and sources of demand

The strategy for meeting the above demand is to use mine dewatering water where ever practical to minimise potential impacts on groundwater resources. Where water demand exceeds dewatering need, early dewatering of below water table pits will be scheduled in preference to developing alternative groundwater supply sources. Where water demand cannot be met from dewatering, then water supply bores will be required along the valley heading eastwards towards Flying Fish.



4.0 IMPACT ASSESSMENT

The impact assessment has utilised a numerical (Feflow) modelling approach to evaluate the following:

- Mine Dewatering – The model was used to simulate mine dewatering according to a preliminary life of mine plan provided by Fortescue. The results of dewatering modelling provided likely abstraction rates to facilitate mining.
- Project Water Balance – The model was used to simulate water supply abstraction from the Wittenoom Aquifer to meet any (potential) deficit in project water demand not met by abstraction for dewatering.
- Potential Impacts – The model was used to assess potential impacts to the environment as a result of dewatering and abstraction of groundwater to meet project demand. The model will be used to assess the magnitude of groundwater level drawdown at and surrounding the site allowing the evaluation of any potential reduction in groundwater supply to surrounding users or the environment to be identified (i.e. groundwater dependant ecosystems).

The results of the numerical 3-D Feflow modelling were coupled with individual mine void analytical models for selected pits.

Due to the complexity and size of the numerical model, it was run in monthly increments over the operational dewatering period and annual time steps during post closure simulations. This was sufficient to provide an understanding of operational water balances and determining impacts such as groundwater level draw down and potential post closure rebound levels.

However, in mine closure there are a number of short comings with the numerical modelling code given that it is designed to represent flow through porous media and abandoned mine pits represent very large open voids or water bodies that make numerical modelling approaches unstable. In normal circumstances a groundwater model would apply head dependent boundaries to such water bodies to determine the flux between groundwater and the water body. However in the case of mine closure, predicting the water body or mine void level is the objective, and thus normal head dependent representation is not appropriate.

Whilst the numerical model has been run for various closure scenarios to estimate groundwater level recovery it has short comings in dealing with mine void lake level recovery and changes in the surface area for physical occurrences such as evaporation from a changing water level of a mine void lake. To account for this and other issues such as intra-annual variability, analytical models were built of individual mine voids that are discretised into daily time steps and run until steady state is achieved or up to 75 years. Daily time steps are used to capture the variability of climate and its impact on water level and water quality over time within mine voids. The analytical mine void models rely on some predictions from the 3-D numerical model, such as predicted sub catchment boundary post closure groundwater level. The advantage of the analytical modelling approach is that allowance for surface water management impacts can be included within the mine void water balance as well as greater control over the impact of evaporation on a surface area that changes with time as the mine void lake level changes.

Given the short duration of the local temporal monitoring and the lack of measurements pertaining to significant stresses across the Project area, both the numerical and analytical models employed sensitivity analysis of input parameters to understand the:

- importance of parameters in determination of the type and extent of impacts
- significance of these parameters on impact predictions (i.e. sensitivity)

The two methods also provide a semi-independent check on the results from each other given the level of uncertainty in post closure parameters that may influence mine void water levels or surface water run-off characteristics.

4.1 Application of Numerical Model

The numerical Feflow model was used to predict the dewatering and water supply impacts on the regional groundwater level. The model is discretised into monthly time steps for predicting the cumulative drawdown



affect across the Project area. As the model utilises the relevant partial differential equations of groundwater flow, and comprises a level of complexity commensurate with the geological structure and hydro stratigraphic understanding within the Pilbara setting, it necessarily represents a 'deterministic' model.

The model was calibrated to a hypothetical pre-mining water table and the numerical model water balance was compared with the conceptual hydrogeological model balance described in Golder (2017a). To account for the uncertainty within model parameters such as the specific yield and hydraulic conductivity a series of sensitivity runs (termed scenarios) were conducted whereby these parameters were perturbed through a plausible range based on local hydrogeological testing and analysis, as well as Golder experience.

Subsequent to conducting the mine dewatering and water supply scenarios the numerical model was used for post closure simulations at annual time steps as a method for understanding likely mine void lake level and groundwater recovery extents within the groundwater sub catchments assuming no mine void backfilling.

4.1.1 Numerical Model Scenarios

A total of six scenarios were considered in the impact assessment work. The scenarios considered dewatering, water supply and closure predictions using the adopted range in specific yield (between 1 and 7 %) for the main project aquifers as detailed below:

- Scenario 1 – Dewatering and Water Supply Modelling. 3% specific yield for project aquifers (average) based on current mine plan (Table 2)
- Scenario 2 - Dewatering and Water Supply Modelling. 1% specific yield for project aquifers (lower limit) based on current mine plan (Table 2)
- Scenario 3 - Dewatering and Water Supply Modelling. 7% specific yield for project aquifers (upper limit) based on current mine plan (Table 2)
- Scenario 4 – Maximum Drawdown Impact Modelling. 1% specific yield based on aggressive mine plan between 2018 and 2024
- Scenario 5 – Maximum Water Surplus Modelling. 7% specific yield based on aggressive mine plan between 2018 and 2024
- Scenario 6 – Groundwater Recovery Modelling. 1% specific yield, using groundwater levels at the end of mining (2036) as predicted by Scenario 4 as initial heads and is simulated out to 2136 (100 years post closure)

The assessment of dewatering rates, water supply demand and groundwater level drawdown impacts for Scenarios 1 to 5 were carried out using the groundwater numerical model established for the project which has been described in previous reports (e.g. Golder 2017a and Golder 2017b).

Scenarios 1 to 3 provide a reasonable range in the dewatering abstraction and water supply demand volumes for the project based on the preliminary mine plan. The results of Scenarios 1 to 3 have been presented in a previous report (Golder, 2017c) and are summarised herein. Scenarios 4 and 5 have been modelled to specifically target “worst case” scenarios for presenting the maximum potential impacts of groundwater level drawdown and maximum surplus water discharge to the environment, respectively. This approach is considered relevant to enable the predicted level of impact to encompass the range of expected aquifer parameters and variations in future mine plans.

4.2 Operational Mine Water Balance

The mine water balance is given in Table 3 based on the sensitivity to specific yield within the first three modelling scenarios with respect to meeting the mine plan and life-of-mine water demand. Table 4 provides a summary of the dewatering and supply demand in total volume from each scenario. The results of each of these scenarios is discussed in more detail in Golder (2017c).



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Table 3: Summary of Simulated Water Balance for All Scenarios by Rate (L/s)

Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Scenario/(Sy)	Water Balance																	
1 (3%)	0 L/s					-10 L/s	-45 to -55L/s										-100 L/s	
2 (1%)	0 L/s	-25 L/s			-50 L/s	-90 to 120 L/s												
3 (7%)	+100 -140 L/s					+40 L/s		-20 to 85 L/s			+ 40 L/s		-50/s		-100 L/s		-145 L/s	

Dewatering Supply = Water Demand

Dewatering Supply Deficit

Dewatering Supply Surplus

Table 4: Summary of Simulated Water Balance Volumes (Life-of-Mine period)

Scenario	Total Demand (GL)	Total Dewatering (GL)	Water Supply (GL)	Deficit /Surplus (GL)*
1	92	71	22	+1
2		67	27	+2
3		91	0	-1

* This is an indicator of the error in the ability to manipulate the model with various pumping schedules and is not indicative of an actual project surplus/deficit



4.2.1 Scenario 1 – 3% Specific Yield (average)

The Scenario 1 model assumed a generic specific yield within both the mineralised ore and weathered dolomite of 3%. The predicted dewatering and water supply demand on an annual scale are essentially neutral under this scenario for the first 5 years of mining. Subsequent to this early period water demand increases with a proposed wet process facility. From 2023 water demand for the proposal cannot be met with dewatering and water supply deficit increases with time. This deficit can be met with the commissioning of water supply bores within the valley. Water demand is also met by continuing to pump from dewatering bores after pits have been fully dewatered to make use of existing infrastructure and to limit drawdown extent to already impacted groundwater sub catchments.

Based on the results of the Scenario 1 modelling simulations approximately 76 % of the dewatering demand could be pumped from dewatering bores and the remaining 24 % from water supply bores. The Scenario 1 version of the model indicates that under the base case specific yield conditions, there would be no requirement to dispose of excess water on a long term continual basis. The modelling carried out does not consider the daily variability of demand which may be affected by shutdowns, poor weather or other operational factors and therefore a contingency for short term disposal or retention of excess water needs to be identified.

4.2.2 Scenario 2: 1% Specific Yield (lower limit)

The Scenario 2 model assumed a generic specific yield within both the mineralised ore and weathered dolomite of 1%. This is a conservative case with respect to identifying if the water supply demand can be met if low storage conditions prevail and to provide an estimate of the number of water supply bores which could be required. In this case, predicted dewatering is insufficient to meet the proposal water demand post the first year.

Based on the results of the Scenario 2 modelling simulations approximately 49 % of the total project water demand could be pumped from dewatering bores and the remaining 51 % would need to be sourced from water supply bores. The proportion of water which will need to be sourced from water supply bores is not constant and increases steadily throughout the life of mine. Initially (between 2019 and 2024) the demand to be met by water supply bores is around 40 – 50 L/s (around 35%), however this increases to between 80 and 120 L/s (around 55%) between 2024 and 2032. Between 2032 and the end of mining, up to 160 L/s could be required from water supply bores which is around 90% of the total demand.

The Scenario 2 model indicates that under the low specific yield conditions, there would be no requirement to dispose of excess water on a long term continual basis. Again, the modelling carried out does not consider the daily variability of demand which may be affected by shutdowns, poor weather or other operational factors and therefore a contingency for short term disposal or retention of excess needs to be identified.

4.2.3 Scenario 3: 7% Specific Yield (upper limit)

The Scenario 3 model assumed a generic specific yield within both the mineralised ore and weathered dolomite of 7%. This is a conservative case with respect to dewatering requirements and results in the prediction of the highest dewatering requirement.

The results of the Scenario 3 model indicate that if the higher specific yield conditions prevail within the Project's ore bodies, dewatering rates could exceed project water demand by between 40 and 140 L/s between 2019 and the start of 2025. During this period an estimated 16.5 GL of excess water could be produced which would need to be managed either by aquifer recharge or discharge to the environment. A further 2.6 GL surplus is predicted between 2028 and the end of 2030. However, a change in mine pit sequence or dewatering at Westend and MM4-6 earlier than simulated by the Scenario 3 model runs (i.e. from 2025) could help reduce this excess and balance the deficit predicted between 2025 and 2028.

The total deficit in the water demand across the modelled period is estimated to be around 22.5 GL. Therefore, if all surplus water could be retained through managed aquifer recharge into groundwater sub catchments with no below water table pits, this volume of water could be reused for water supply later in the life of mine when a water deficit is apparent.



The cumulative dewatering rates for the early period of mining (2019 to 2025) required to dewater Talisman, Broadway East, Broadway West and Westside pits are estimated to be up to 270 L/s. This is difficult to avert under high specific yield conditions as early dewatering is required to achieve the groundwater level drawdown at final pit depths in 2023 (Talisman and Broadway East) and 2025 and 2029 (Broadway West and West End).

4.3 Maximum Predicted Groundwater Level Drawdown (Scenario 4)

Groundwater level drawdowns resulting from the proposed mining activities have been estimated using the numerical model. A 'worst case' simulation was undertaken where all pits were dewatered simultaneously, with the maximum amount of water required from water supply bores simulated to assess the impacts of the water supply borefield(s) in addition to dewatering.

The predicted groundwater level drawdowns at 2024, where all pits are modelled to have been dewatered, are shown in Figures 5A to 5D and are based on the low storage scenario (1% specific yield) to provide further conservatism regarding the drawdown footprint. In Figures 5A to 5D, groundwater level drawdown contours are shown for groundwater sub catchments which do not have below water table pits but where abstraction of groundwater has been modelled for the purpose of meeting water supply. The groundwater level drawdown contours presented in pale blue are for the purpose of differentiating between impacts caused by dewatering (dark blue) and water supply (pale blue).

Groundwater level drawdowns predicted for both dewatering and water supply typically extend across all of the groundwater sub catchments in which these activities are proposed. Consistent with the compartmentalised nature of the groundwater system across the Project, groundwater level drawdown contours do not extend beyond the low permeability geological units/structures which delineate each groundwater sub catchment. As a result, groundwater level drawdown predicted for the project is limited to within the project bounds and off lease impacts are expected to be negligible.

Plots of groundwater level drawdown over the dewatering and water supply periods are shown at each of the groundwater model tracking points in Appendix A.

4.4 Maximum Predicted Water Surplus (Scenario 5)

The maximum likely surplus water volumes were estimated using the simultaneous pit dewatering approach as per Scenario 4 but with 7% specific yield (Scenario 5). The results of Scenario 5 indicate that up to 49 GL of surplus groundwater may need to be managed throughout the first 5 years of mining (2019 to 2024) given the assumption all below water table pits are mined and dewatered simultaneously at the commencement of mining. The estimated rates of surplus water generated as a result of following the aggressive mine dewatering schedule (conservative estimate) are between 150 and 350 L/s (refer Figure B).

4.4.1 Surplus Water Management Options

Where dewatering is generating a consistent daily surplus to demand the options presented in Table 5 for assessment of release or re-use of water have been considered.



Table 5: Surplus water release or re-use options

Management Option	Site specific consideration
Relocation for use nearby	The Project represents a remote Operation with negligible adjacent industries for use nearby. Other users in the area comprise pastoralists, with small demand, or other mining centres. The three nearest mining centres, RTIO's Brockman 4, Brockman 2 and Nammuldi Operations, all have surplus water balances with no perceived need for alternate sources
In pit storage	In pit storage for later re-use is a viable option for surplus water management once mined out pits are established. There are a number of above water table where surplus water could be stored for either re-use or for infiltration back to the water table. This would require a mine plan that focused on AWT pits early within the mine life to provide the completed pits prior to dewatering BWT pits.
Aquifer reinjection	This option has potential along the valley floor between the Marra Mamba Iron Formation pits once dewatering of nearby pits has been facilitated. Risks of waterlogging at injection head and well clogging would require careful management.
Controlled discharge	Controlled discharge comprises the release of surplus water through a pipe line or overland diversion to a designated water course or wetland determined by the department and proponent. This option could be utilised to minimise the extents of drawdown, where groundwater dependent vegetation is at risk from dewatering. Controlled discharge may be warranted along Pinarra Creek and gorge area to sustain vegetation, particularly if land use changes, surface water diversions or creek capture minimise the frequency of low flow events that may sustain riparian vegetation.
Uncontrolled discharge	Whilst a definition of uncontrolled discharge is not provided by the Department of Water, it is not in the proponent's interests for effective mine planning and dewatering for the uncontrolled release of surplus water where re-circulation to mine pits or impacts to infrastructure corridors may occur. It is not considered a viable option within the limited tenure (area) available.

Given the circumstances around the Project area, a remote site with limited water demand centres in any proximity, the viable surplus water management options comprise in pit storage, aquifer reinjection and controlled discharge. In pit storage will be contingent on a mine plan that is water sensitive and accounts for the need to store surplus dewater in mined out pits. An example would be scheduling for large scale dewatering of multiple pits subsequent to the completion of smaller AWT pits that could be used to store water. Controlled discharge could be conducted within tributaries to either the Boolgeeda or Duck Creek catchments, both of which are part of the larger Ashburton catchment. Controlled discharge could also be used to supplement those areas deemed to be groundwater dependent that are to be impacted by dewatering draw down.



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Due to their proximity to the mine pits, and relatively deep water table, groundwater sub catchments 502 and 519 (Figure 3B) are potential options for reinjection of surplus water. An analytical assessment of the potential volume of water which could be stored in these sub catchments on a conceptual basis is presented in Table 6. The results of these calculations indicate that the 519 groundwater sub catchment is the most suitable option for storage of surplus water by aquifer injection, based on estimated (potentially available) storage.

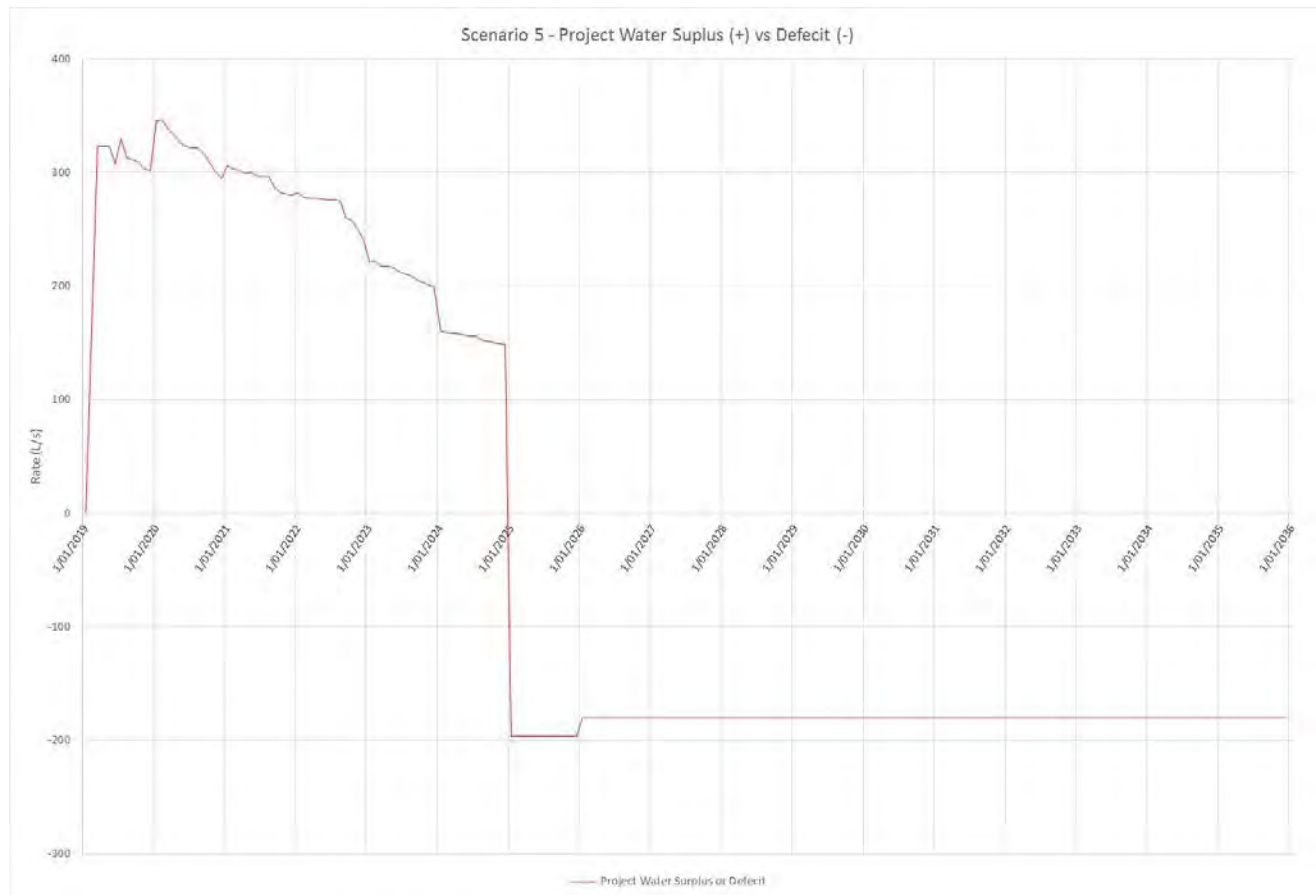


Figure B: Scenario 5 - Surplus vs Deficit

Table 6: Estimate of Storage Capacity for Groundwater Sub Catchments

Groundwater Sub Catchment	Lowest Ground Elevation (m AHD)	Possible Groundwater Level Rise (m)*	Estimated Area (km ²)	Specific Yield	Volume of Water Potentially Stored (GL)
502	530	13	8.7	1%	1
				3%	3
				7%	8
517/519	570	36	27.4	1%	10
				3%	30
				7%	69

*Assumed groundwater level allowed to rise to a maximum of within 15 m below ground level



4.5 Groundwater Level Recovery Post-Closure (Scenario 6)

The Scenario 6 model run was carried out to provide an estimate of the post closure groundwater level recovery over a 100-year period from the predicted completion of mine dewatering and water supply abstraction activities.

The rates of recovery of groundwater levels, following mine closure, were estimated using the same 'tracking points' designated in the model to generate hydrographs for mine dewatering and water supply. These hydrographs are presented in Figure C.

The results of Scenario 6 indicate that the range in residual groundwater level drawdown between pre-mining levels and 100 years post closure is between 1 and 37 m. A summary of the residual groundwater level drawdown after 100 years on a groundwater sub-catchment basis is contained in Table 7.

Table 7: Post Closure Groundwater Level Recovery

Groundwater Sub-Catchment (m)	Pit Name or Water Supply Wellfield	Estimated Post Closure Groundwater Level (m AHD)	Predicted Residual Drawdown after 100 years (m)	Tracking Point Reference
393	Broadway West	383	10	TP_7
457	Westend	455	2	TP_1
459	Broadway East	458	1	TP_5
474	Talisman	464	10	TP_8
502	502_1 and 502_2	484	18	TP_13
510	Eagles Nest	485	25	TP_14
517/519	519_1, 519_2, 519_3, 519_4, 519_5 and 519_6	494	25	TP_15
500	MM4-6	476	24	TP_16
497	497_1, 497_2 and 497_3	480	17	TP_19
544	544_1, 544_2 and 544_3	507	37	TP_21
553	553_1	529	24	TP_22

The results presented in Table 7 are based on modelled Scenario 6 where the specific yield of each aquifer is set to 1%. Based on Golder's experience in the Brockman Syncline, 1% is considered to be at the low end of the possible range in specific yield values and therefore the magnitude of drawdown across groundwater sub catchments predicted at the end of dewatering is more likely to be an over estimate (conservative). However, under these conditions, the rate of groundwater level recovery following mine closure could be more rapid than would be expected for an aquifer with higher specific yield values. These effects possibly offset each other in the estimates presented in Table 7 for the residual drawdown 100 years after the completion of dewatering/water supply abstraction.

The extents of groundwater level drawdown at the locations of below water table mine voids are expected to be similar for both the 7% (upper) and 1% (lower) specific yield scenarios since in each case the pits must be dewatered to facilitate mining. The recovery of groundwater levels is expected to be slower in the 7% specific yield case.



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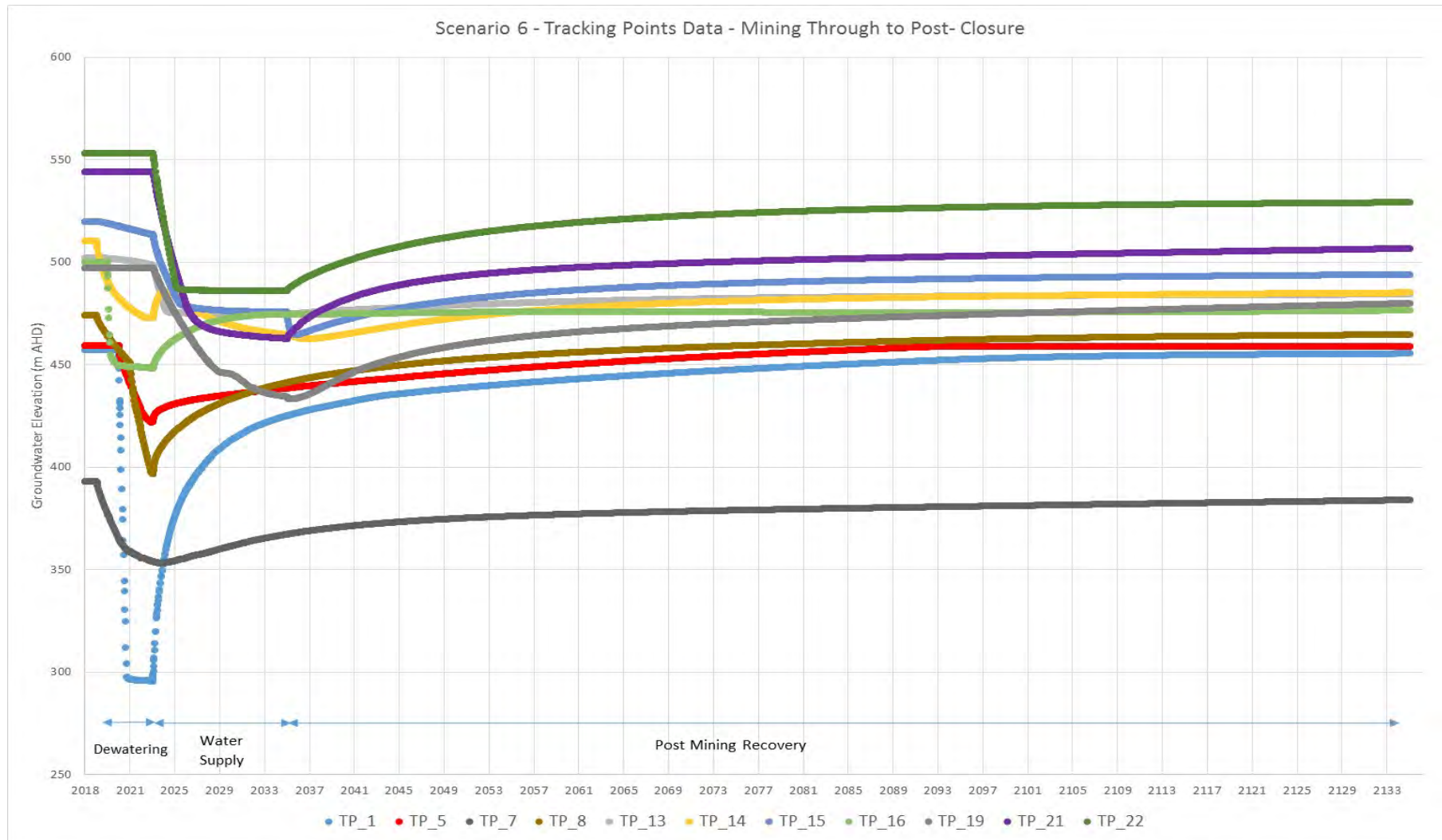


Figure C: Predicted Post Closure Groundwater Level Recovery with no mine void interaction



4.6 Post-Closure Mine Voids

At closure, the Project is likely to comprise both above water table and below water table pits (voids) that have not been backfilled. Some of these mine voids, owing to their location in a narrow drainage valley, may also intersect existing drainage lines and thus capture surface water flow during run-off events from significant catchments. As a consequence, there will potentially be a number of different types of water bodies present at closure. The proposed nomenclature adopted for mine voids in this report is as follows:

- **Groundwater dependent mine void lakes** – comprise below water table mine voids that are principally supported by groundwater inflow and have negligible surface water input. They are expected to be perennial water body features within the post closure landscape, i.e. mine void lakes.
- **Groundwater – Surface water mine voids** – comprise shallow below water table ore bodies that may receive some groundwater input as well as surface water input from catchments that are significantly greater in area than the pit shell itself. They are expected to be perennial water body features within the post closure landscape.
- **Surface water dependent mine voids** – comprise above water table pits that will receive surface water run-off input from catchments that are significantly greater in area than the pit shell itself. These mine voids are expected to be ephemeral but with potential for inter-annual flooding, depending on antecedent climatic conditions.

The conceptual pre mining and alternate post closure mine void types are presented in Figure 6.

The recovery of groundwater levels post mining was estimated using the numerical model Scenario 6 by extending the Scenario 4 simulation post mining for 100 years and the characteristics of the post mine closure void lakes were assessed using analytical water balance methods for a selection of mine voids requiring dewatering.

4.6.1 Analytical Methods

Each mine void analytical water balance representation comprised the following inputs and outputs.

- Groundwater & Groundwater - Surface water dependent mine void lakes
 - Rainfall as direct recharge to mine void lake surface
 - Rainfall run-off from mine void walls
 - Head dependent groundwater inflow based on the sub catchment boundary head post dewatering and the head in the mine void lake
 - Evaporation from the mine void lake surface
 - Surface water catchment inflows
- Surface water dependent mine voids.
 - Rainfall as direct recharge to mine void surface (or ephemeral lake surface)
 - Rainfall run-off from mine void walls
 - Evaporation from the mine void surface (or ephemeral lake surface)
 - Surface water catchment inflows

The range in initial groundwater levels at the groundwater sub catchment boundary were derived from the output of Scenarios 4 and 6 numerical models. The highest head used was the post closure head predicted by the groundwater model at the nominated tracking point at 2136 (Scenario 6). The lowest head used was the head predicted at 2024 (end of dewatering period) in Scenario 4 along strike from the mine void within



each individual groundwater sub catchment. The analytical model head dependent boundary inputs derived from the numerical model are provided in Table 7.

The groundwater head post mining beneath the pit was often predicted to be lower than the pit minimum bench RL. In such cases there was a hysteresis between the end of pumping and when the head in the aquifer reached the pit floor. As the analytical models represent a water balance for the mine void, they commence from when the groundwater level intersects the pit floor and the time taken for this to occur is not represented within the analytical models. The period over which groundwater levels are expected to recover from dewatered levels up to the base of the mine void varies between locations and ranges from periods of weeks (Westend and MM4-6), several years (Talisman), decades (Broadway East and West and Westside) and not at all at Eagles Nest. These estimates, however, do not consider the potential for the rate of groundwater level recovery being accelerated through the capture of surface water within pit voids from the surrounding catchment.

Within the analytical models an interpolation function based on 1m depth increments for each pit shell and volume was used to convert water levels to volumes for the adding and subtracting of volumetric inputs and outputs. An interpolation function given 1m increments for each pit shell and total surface area as either lake or pit wall was used for pit wall run-off calculations and evaporation from the lake surface.

Surface water catchment areas were provided by Fortescue for the post closure land form and used with a catchment run-off value for rainfall at the assumed point at which run-off is considered likely to occur and a percentage of that run-off then adds water to the mine void. A synthetic series of daily rainfall and evaporation data was generated from the Scientific Information for Land Owners (SILO) database given the midpoint location of the Project area. SILO presents gridded rainfall and evaporation data based on rainfall records from 1889 to present day.

Sensitivity testing was undertaken for parameters including hydraulic conductivity of basement wall rock, specific yield, pan evaporation factor, rainfall run-off co-efficient, rainfall deficit amount (the amount of rainfall required before rainfall is included as recharge) and nature of surface water events. A description of the analytical model process and parameters is contained in Appendix B. A summary of generic input and the range in parameter variables used is contained in Table 8. The baseline runoff variables applied to the synthetic rainfall data resulted in average annual runoff similar to those generated from the CSIRO Pilbara water resource assessment for the Ashburton Robe region (McFarlane, ed. 2015). A summary of catchment specific variables and ranges is contained in Table 9.

Table 8: Analytical model parameter ranges used in sensitivity testing

Parameter	Range
Hydraulic conductivity	0.01 to 5 m/day
Pan evaporation factor	0.4 to 0.6
Pit wall rainfall cut-off	0 to 5 mm
Surface water catchment rainfall cut-off	20 to 30mm
Run-off coefficients	10 to 50%



Table 9: Catchment specific parameters and ranges used in sensitivity testing

Mine void model	Parameter	Range
Westend	Surface water catchment area	0
	Head dependent boundary	440 to 470m RL
	Distance to boundary (effective radius)	2.8km
Talisman	Surface water catchment area	13.0km ²
	Head dependent boundary	420 to 465m RL
	Distance to boundary (effective radius)	2.5km
Broadway West	Surface water catchment area	50.2km ²
	Head dependent boundary	360 to 380m RL
	Distance to boundary (effective radius)	6.3km
MM4-6	Surface water catchment area	28.4km ²
	Head dependent boundary	450 to 475m RL
	Distance to boundary (effective radius)	2.6km
Westside	Surface water catchment area	0
	Head dependent boundary	470 to 480 m RL
	Distance to boundary (effective radius)	8.5km

The head dependant boundaries used to calculate the groundwater inflow/outflow for each mine void was constant for the duration of the model simulation. In reality, it is possible that the head boundaries change over time if significant inputs of catchment run-off enter the groundwater sub catchment resulting in recharge or with significant cumulative outflow as a result of evaporative loss from mine void lakes. These processes have not be considered in these mine void calculations.

4.6.2 Groundwater dependent mine void lakes

The main groundwater dependent mine void lakes are likely to be associated with the deep Brockman Iron Formation Westend and Westside pits. These pits are located high on the northern syncline limb range of hills and thus have negligible surface water catchments outside of the bunded pit crests.

For Westend, the planned mine depth is approximately 150m below the pre mining water table. Sensitivity of the mine void lake levels were tested for the following parameters, hydraulic conductivity, the head dependent groundwater boundary level post mining, pit wall run-off coefficient and pan evaporation factor.

Varying the hydraulic conductivity for the groundwater inflow either shortened or lengthened the time until the mine void lake level reached steady state. With hydraulic conductivity in the order of 1m/day, steady state was reached within 30yrs of mine closure, with a hydraulic conductivity two orders of magnitude lower, steady state is estimated not to have been reached by 2100 (end of simulation time).

The head dependent boundary condition applied within the catchment determined the final mine void steady state lake level attained. The boundary head was simulated at 440 and 470m RL based on the Scenario 4 model output. When the head dependent boundary was in the order of 470m RL the mine void recovered to a steady state level of ~460m RL with the mean hydraulic conductivity scenarios. When the boundary head was 440m RL the mine void was predicted to recover to around ~438m RL with the mean hydraulic conductivity scenarios. The pan evaporation factor was perturbed between 40 and 60%, with the difference in predicted mine void lake levels (when all other parameters were kept constant) being in the order of a few metres, which is somewhat insignificant for a lake of up to 100m depth.

Varying the pit wall run-off between 20 and 50% of daily rainfall accelerated the time until steady state was reached, and if it was assumed to be higher, then this resulted in the mine void becoming a recharge lake when the mine void water level exceeded the head boundary condition, however this upper value is



considered unlikely. There was no addition of a surface water catchment input given the location of the mine void in the range lands.

A groundwater dependent lake was predicted in every sensitivity scenario run with the perturbation in parameters impacting either the time to reach steady state (30 to >75 years) or the actual mine lake level (~380 to ~460m RL). In all cases, with the exception of the high runoff (>50%) case, the predicted lake represents a groundwater sink with a lake level between 0 and 50m below the pre mining groundwater level. Predicted mine lake recovery levels over time are provided in Appendix C for each scenario.

4.6.3 Groundwater – Surface water dependent mine voids

Most of the below water tables pits within the valley floor comprise groundwater – surface water mine voids owing to a combination of the relatively shallow depth of mining below water table, the compartmentalised nature of the groundwater sub catchments and the potential for capture of surface water catchments in excess of any bunded pit crest area. The mine voids within this category comprise Talisman 2, Broadway West 3, Broadway 1, MM4-6 and Eagles Nest.

The critical element that determines whether these mine voids will become perennial or ephemeral water bodies is the head dependent boundary condition that drives groundwater input or loss. If the boundary head is greater than the minimum mine bench RL then the mine voids will tend to become perennial water bodies. However, if the head dependent boundary condition is equal to or less than the minimum mine bench relative level then the mine void will tend to be ephemeral. In these cases the mine void water bodies are assessed to likely form “swamp lands or marshes” with groundwater levels recovered to or just below the minimum mine bench RL. This predicted outcome occurs when the dewatering of the groundwater sub catchment extends to a head at the flow boundary that is less than the minimum mine bench RL. As a consequence, there is no groundwater input, and when the pits are filled with rainfall or surface catchment and pit wall run-off, mine void lake volume is lost by flow out to the groundwater system (as groundwater head is lower than lake level) and evaporative loss over time.

Periodic inundation of the mine voids from surface water inflow is common with variable depth and duration, which can sometimes extend to multiple years. The parameters that change the period of inundation comprise both the hydraulic conductivity, with a lower hydraulic conductivity meaning the lakes drain slower, and those parameters associated with surface water catchment run-off, with a high run-off delivering more surface water to the pit.

The depth of inundation is predicted to vary from 15m for Talisman, by up to 30m at Broadway West and nearly 40m at MM4-6. The maximum increase in depth of inundation occurs when inflows are to an empty void, a smaller increase in depth is modelled when groundwater levels are above the base of the pit maintaining a base fill level. This is due to the shape of the mine voids where lower elevations require less volume to fill.

Predicted mine lake recovery levels over time for each modelled scenario are provided in Appendix C for Talisman, Broadway West and MM4, including tables with the range in parameters represented within the models. When comparing the range in peak lake levels between the three mine voids (Talisman, Broadway West and MM4-6) it is apparent that the larger the surface water catchment area, the greater the impact of varying the surface water run-off variables have on lake levels. Broadway West has a surface water catchment area four times the size of Talisman and as such has a significantly greater range in peak mine void lake levels (up to 30m).

With the exception of Broadway West with its large surface water catchment, groundwater – surface water dependent mine voids do not appear to be at risk of over topping based on the synthetic rainfall dataset from SILO and the baseline runoff parameters applied. At Broadway West there are numerous scenarios where the pit crest could be breached and over topping of the pit mine void is possible. These include whenever boundary head conditions are, high catchment run-off values are applied or the hydraulic conductivity is very low (trapping water in the mine void for longer allowing subsequent runoff events to fill the mine void).

Elsewhere, if the catchment run-off values are high and the hydraulic conductivity is low (refer to Appendix C), then the decline in lake level will be slow and subsequent surface flow inputs can cause further increases



in mine void lake levels. Under these conditions, a perennial lake is predicted even when the head boundary condition is lower than the final mine void bench level.

There is negligible impact in perturbing the pan evaporation factor with a variation of 10% impacting predicted lake levels by approximately (only) a metre.

4.6.4 Surface water dependent mine voids

The surface water dependent mine voids represent those that lie above the water table mine voids that required no dewatering, but owing to their location within their catchment are at risk of intercepting or capturing surface water flow from a larger catchment. The behaviour of these landforms will be similar to the groundwater - surface water dependent mine voids, except that they are more likely to be ephemeral and will only be perennial mine void lakes if the catchment areas and run-off coefficients are sufficiently large and the hydraulic conductivity sufficiently low such that the mine voids are constantly re-filled prior to loss to groundwater and evaporation have time to empty them.

No analytical simulations have been conducted for these mine void types as there is insufficient surface water catchment area and/or pit depth versus volume relationships were unavailable.

4.6.5 Mine Void Lake Chloride

The Chloride ion is a conservative ion (occurs in relative constant proportion and is not impacted by biological factors) and as such represents a proxy for estimating mine void lake water quality changes over time. Chloride concentrations of the mine void lakes have been estimated using the predicted inflows and outflows on a daily basis and multiplying these by the assumed Chloride concentrations expected for each of the inflow/outflow processes. Given the uncertainty in the expected chloride concentrations, sensitivity testing was undertaken for the chloride ion concentration variables.

The main input and output variables comprise catchment groundwater and surface water flow event chloride concentrations, and to a lesser extent rainfall and pit wall chloride concentrations. The assumed groundwater chloride concentrations were derived from the analysis of groundwater samples taken from the western (Eliwana) production bores which ranged between 91 and 211mg/L with a mean of 148mg/L from a sample size of 10. Eastern (Flying Fish) groundwater chloride levels were not used as they were significantly different from Eliwana (>350mg/L) and no Flying Fish mine voids were simulated as they fall within the surface water dependent category only. Pilbara rainfall Chloride ion concentrations have been reported by Hedley et al., (2009) at 0.5mg/L.

There is a high degree of uncertainty in the expected chloride concentration of surface water events and from pit wall run-off events. In surface water catchments chloride concentrations of ephemeral stream flow events will be influenced by rainfall intensity and duration, and antecedent catchment conditions. Furthermore, there is very limited information or collection of stream flow event water quality owing to flow events representing "flash floods". Chloride concentrations reported for the Ashburton River catchment from the DWER Water Information database vary between 3 and 127 mg/L with a mean of 77mg/L and sample size of 5. The samples are listed as "grab samples" from river or stream with an absence of information on the nature of the flow occurrence, e.g. flash flood, flowing waterway or isolated to stagnant evaporated pool. Given this uncertainty sensitivities were run on chloride concentration inputs to understand the importance and impact of understanding the respective parameter ranges. The ranges of values for each parameter in the salt balance are provided in Table 10.



Table 10: Salt balance parameter ranges in chloride concentration

Mine void model	Parameter	Base	Sensitivity
Westend	Rainfall chloride	4 mg/L	NA
	Pit wall chloride	250 mg/L	500 mg/L
	Groundwater chloride	150 mg/L	500 mg/L
Broadway West & Talisman	Rainfall chloride	4 mg/L	NA
	Pit wall chloride	20 mg/L	2500 mg/L
	Groundwater chloride	100 – 500 mg/L	1000 mg/L
	Surface water chloride	10 mg/L	1000 mg/L

Chloride mass balances were calculated for a groundwater dependent mine void lake (Westend) and variable groundwater – surface water dependent mine void lakes (Broadway West and Talisman), in which the analytical model water balances indicated either perennial and or ephemeral mine void lake outcomes. The chloride mass balances assume instantaneous mixing and make no allowance for the potential for density or temperature stratification of mine voids lakes (common to deep lakes such as the predicted Westend mine void lake).

4.6.5.1 Groundwater dependent mine void chloride concentration

The chloride concentration of the Westend mine void was predicted to increase over time without reaching steady state. The rate of increase given the variations in water balance inputs was in the order of 400mg/L per 50 years. The higher concentrations were associated with the high hydraulic conductivity scenarios, resulting in higher lake levels and hence more surface area for evaporation. The lower predicted concentrations were associated with low head dependent boundary or high pit wall runoff scenarios when the assumed pit wall runoff chloride concentration was low.

A sensitivity run was performed by doubling the groundwater chloride concentration and another by doubling the pit wall runoff concentration as the two main contributing inputs to the mine void lake level. The base cases used for the sensitivity runs were the mean hydraulic conductivity and higher groundwater head values for each mine void model. Doubling the groundwater chloride concentration resulted in the rate of change increasing to ~800mg/L per 50 years. Doubling the pit wall runoff concentration resulted in a minimal rate of change in the chloride concentration in comparison to the base case (~400mg/L per 50 years).

Graphs of chloride concentration over time given variable water balance and chloride concentration inputs are provided in Appendix C.

4.6.5.2 Groundwater – Surface water dependent mine void chloride concentration

The chloride concentration of the Broadway West and Talisman mine voids was predicted as a proxy for all other groundwater – surface water dependent mine void lakes. In the cases where the head dependent boundary condition was lower than the base of the minimum mine bench RL, and the lakes were predicted to be ephemeral, there were negligible increases in the chloride concentration above 200 mg/L. This is owing to the assumption of relatively fresh rainfall runoff from surface water catchments contributing to the mine void; and that water from the mine void lake was then lost to seepage to the water table with limited opportunity for evaporation to concentrate salts. Once the mine void was dry, the next influx of fresh water run-off essentially reset the chloride concentration as no allowance was made for any salts accumulated on the pit floor walls or surface.

In cases with a higher assumed head dependent boundary, or alternate conditions such as very low hydraulic conductivity and/or high surface water catchment run-off, perennial mine void lakes occurred, although there was a difference in the behaviour of Talisman and Broadway West. The perennial Talisman mine void lake had chloride concentrations that were predicted to increase at a rate of approximately 100 to 200 mg/L over 50 years. At 50 years there is conjecture as to whether the chloride concentration is close to



steady state with a large temporal variability dictated by decadal cycles between wet and drier periods. The perennial Broadway West mine void lake, owing to the much larger ratio of surface water catchment area to mine void volume, the chloride concentrations are predicted to reach a steady state roughly equivalent to the assumed surface water runoff input concentration.

The initial increase in chloride concentration predicted for the Broadway West pit void lake (roughly first 5 years after groundwater recovery to the base of the pit) is due to the absence of significant catchment runoff events which provide inputs of large volumes of much lower chloride concentration water. Prior to this, the main inflow of water into the pit void was from groundwater (172 mg/L) and pit wall runoff (250 mg/L) which is much higher than estimated for the catchment runoff (10 mg/L).

For Broadway West, the initial steady increase in chloride concentrations is a result of the lack of significant rainfall events which means the chloride brought into the mine void by groundwater inflow is allowed to evapoconcentrate as the only flux out is via evaporative loss. Once a significant amount of rainfall occurs (after around 5 years in the simulation) there is a significant reduction in chloride concentrations as the rainfall is fresher, diluting mine void lake chloride. In addition, following this rainfall, the mine void lake level is elevated above the regional groundwater head boundary resulting in some groundwater loss to the aquifer which causes a further reduction in total chloride load within the mine void.

Sensitivities were performed on the pit wall and surface water and groundwater chloride concentration inputs for both mine voids. In both cases the predicted results were most sensitive to the assumed surface water catchment runoff chloride concentration. At Broadway West, the pit wall runoff concentration did not influence the predicted mine void chloride concentration, however the catchment surface water input concentration had a substantial effect (i.e. mine void concentrations were much more sensitive to catchment chloride concentrations). At Talisman there was a larger evaporative effect with chloride concentrations increasing by 400mg/L above the input surface water concentration over 50 years. The Talisman mine void was also somewhat sensitive to groundwater chloride concentration, with an order of magnitude increase in groundwater chloride (to 1000mg/L) resulting in an increase in mine void lake chloride concentration by around 400mg/L (with high temporal variability). Neither mine void was sensitive to the pit wall chloride concentration, meaning accumulated residual salts on the pit floor are unlikely to influence chloride concentration in ephemeral mine voids.



5.0 DISCUSSION

5.1 Other Groundwater Users

There are no water source protection areas, public drinking source areas, National Parks, estates or other users that will be impacted by the dewatering based on the simulated extents of groundwater level drawdowns.

Other groundwater users comprise pastoral land holders with small water demand for cattle and other iron ore mining operations. All open cut iron ore mining operations within the Brockman syncline currently operate with surplus water to demands. These operations discharge surplus water to creek lines or use the water for alternate schemes, such as the Nammuldi Agricultural Project (NAP).

5.2 Groundwater Dependent Ecosystems

Fortescue supplied flora maps of local vegetation assemblages that were used to delineate the locations of vegetation assemblages that may be groundwater dependent² based on the species observed. Trees accessing groundwater could be impacted by any drawdown in groundwater levels at a rate or to a reduced level outside the bounds of natural variation.

Potential groundwater dependent vegetation (GDE) types in the Project area comprise riparian vegetation assemblages. Two main assemblages were mapped; one comprising *Eucalyptus xerothermica*, *Corymbia hamersleyana* and *Acacia aptaneura* woodland over open shrub land and grassland in the east (Flying Fish) area; and *E. victrix* and *E. xerothermica* woodland over acacia shrub land and spinifex tussock or hummock grassland in the west along Pinarra Creek.

The two vegetation assemblages were mapped in four separate areas and the validity of these assemblages being groundwater dependent was discussed in Golder (2017a) given an analysis of the depth to groundwater from local monitoring bores and or conceptual water table interpretations. In summary, the dependence on groundwater was thought to be limited to the following areas within the mapped potential GDE (PGDE) vegetation assemblages.

- PGDE1 - From Baddock Bore for an approximately 2 km length of Pinarra Creek upstream from where the creek turns south and cuts through the Brockman ridge (see Figure 5B).
- PGDE2 - A 2 km length of unnamed creek running north to south, west of FFPB003 (near TP_19 on Figure 5D)
- PGDE 3 - A 6 km section of unnamed creek running from NE to SW past FFPB001 (see Figure 5D) and cutting across the Brockman ridge to the internal syncline valley and Boolgeeda Creek.

The following description of the drawdown in these areas is based on the results of the Scenario 4 numerical modelling run. The depth to groundwater predicted by the model over the dewatering, water supply and post closure periods, for each of the following points, is presented in Appendix D at the tracking points outlined below (and as shown in Figures 5B to 5D):

- PGDE1 – TP4, Baddock Bore, TP5 and TP6
- PGDE2 – 497_GDE_1
- PGDE3 – FF_GDE_1 and FF_GDE_2

These drawdowns are the worst case possible given that all the dewatering of the below water table pits is facilitated within the first five years in the Scenario 4 schedule and subsequently water supply is derived from new catchments further east, which is highly unlikely given the currently assumed sequencing in the mine

² In this instance groundwater dependence is assumed to include either phreatophytes that access groundwater directly or vadophytes that access the vadose zone above the water table.



plan. Furthermore, Scenario 4 assumes a low specific yield (Sy 1%), accentuating potential impacts from groundwater pumping.

The area from Badock Bore downstream comprises the area of the Pinarra Creek gorge where it turns south southwest and cuts through the Brockman Iron Formation range. At Badock Bore to the north of the Mount McRae Shale drawdown is predicted to be in the order of 30m beneath the mapped GDE. Assuming dewatering is affected within 5 years then the rate of decline in groundwater levels would average 16mm/day. South of the Mount McRae Shale outcrop at the northern end of the gorge the drawdown is predicted to be 20m and reduces to 10m at the point of the Joffre Member dolerite sill. Whilst not explicitly depicted, drawdown is not anticipated to occur south of the Yandicoogina Shale at the top of the Brockman Iron Formation.

Predicted drawdown along the unnamed creek where groundwater levels are expected to support riparian vegetation (GDE) are in the order of 70 to 80m within the valley. Assuming that water supply pumping occurs for the final 10 years of mine operations then the rate of decline in groundwater levels would be in the order of 22 mm/day. South of the outcropping Mount McRae Shale the impact of water supply pumping is mitigated by the impermeable nature of this unit. Nonetheless, groundwater level drawdowns are predicted to be in the order of 40m at the Joffre Member dolerite sill and up to 20m on the south side of the sill. To the north end of the GDE, drawdown is predicted to be in the order of 20m within the lower Marra Mamba Iron Formation and up to 10m within the upper members of the Jeerinah Formation of the Fortescue Group.

The final GDE location had water supply pumping represented in the 553m RL groundwater sub-catchment where approximately 2km of GDE is mapped. The drawdown was predicted to be in the order of 80m within the valley reducing to the north and south owing to the relatively impermeable geological members and formations in either direction. Similar to above the rate of decline in groundwater level would be in the order of 22 mm/day. The predicted drawdown in this catchment is impacted by the nearby model boundary head that is located at an inferred dolerite dyke given the change in head either side of the dyke. If this dyke is leaky then the drawdown within the GDE is not likely to be as great but would extend further to the east along the strike of the valley.

Given the above discussion, the areas determined as potentially GDE based on vegetation mapping and interpreted groundwater level contours would be impacted by dewatering in the west; and by water supply abstraction in the east.

5.3 Cumulative Impacts

The Project comprises a multi-pit mine with pits extending below the water table. Potential impacts to groundwater relate to dewatering for mine void development, drawdown as a consequence of mine water supply, discharge of surplus water to drainage lines or via reinjection, changes to groundwater quality, changes to land forms, diversion or capture of surface flow and potential for changes to the pre-mining recharge regime.

These impacts will be limited to the extent of Fortescue's mining lease with the exception of the option for discharge of surplus mine water to drainage lines which may result in surface flow across Fortescue's tenure boundary. The impacts are cumulative with respect to the Brockman Syncline bioregion given the pre-existing mine footprints in the area as a consequence of approved Rio Tinto operations at Brockman 4, Brockman 2 and Nammuldi / Silvergrass mines.

Rio Tinto's approved impacts comprise the following components outlined in Table 11.



Table 11: Approved mining related impacts at Brockman Syncline

Physical element	Activity	Authorised extent
Marra Mamba & Brockman Iron Formation open cut pits (Nammuldi-Silvergrass Expansion MS No. 925)	Dewatering	Mining up to 225m below the water table
	Dewatering	No more than 51GL/a
	Management of surplus water	Transfer for irrigated agriculture Periodic discharge to Duck creek
Detrital pits open cut pits (Brockman 2 detrital mine MS No. 867)	Dewatering	1.2 GL over the life of project
	Management of surplus water	Discharge to Pit 5 of no more than 950ML/a
MS No. 867 Condition 9-3.	Closure	Backfill the BS2 pit with inert waste to sufficient depth to ensure that following closure groundwater would not permanently remain at least 3m below the lowest point of the pit floor.
Brockman & Marra Mamba Iron Formation open cut pits (Brockman Syncline 4 revised proposal MS No. 1000)	Management of surplus water	Disposal through controlled discharge to Boolgeeda Creek. Discharge to extend no further than 37km along Boolgeeda creek from discharge point under no flow conditions
	Closure	Mine pits to be backfilled above the pre mining water table to prevent the formation of pit lakes

The potential cumulative impacts related to groundwater comprise dewatering, the changes to landforms between pre and post mining that alter recharge regimes, disposal of surplus mine dewater during operations and the generation of mine void lakes on closure.

Given the Project proposal, and the above approved impacts, the most likely cumulative impacts comprise:

- Cumulative dewatering of 'palaeo' groundwater from the Brockman syncline (whilst the drawdown cones from each operation are not anticipated to coincide, overall there will be a loss of stored groundwater across the syncline).
- The cumulative discharge of surplus water from the Project area, if it was to occur to Pinarra Creek, may mix with discharge from the Brockman 4 Operation to Boolgeeda Creek and breach the existing approved limit of 37km flow from the Rio Tinto discharge point described in Ministerial Statement 1000. Alternatively, discharge to a tributary to the north of the Project could mix with the periodic discharge from Nammuldi Silvergrass to the Duck Creek catchment.
- Generation of mine void lakes at Nammuldi and the Eliwana Mining Project. Both of these operations occur on the northern limb of the syncline, whereas Brockman 2 and Brockman 4 have conditions that require no perennial pit lake mine voids to remain at closure.

5.4 Sensitivity and Uncertainty

5.4.1 Hydrogeological Conceptualisation

The hydrogeological conceptual model was reported in Golder (2017a) given measured water levels from mineral exploration holes, hydrogeological investigations including test pumping, geological models and outcrop, short term temporal water level monitoring from constructed bores and Golder's experience across similar catchment characteristics within the Hamersley province. A central pillar of the conceptual model is



the strata bound nature of the fractured rock environment and distribution of aquitards within this setting. The aquitards comprise the Yandicoogina Shale Member, a dolerite sill within the Joffre Member, the Mount McRae Shale and the lower Marra Mamba Iron Formation members. These are hypothesised to limit across strike hydraulic connection (as seen at other Pilbara operations). Furthermore, groundwater flows are constrained or impeded entirely by a series of dolerite dykes that trend NW-SE or SW-NE, limiting hydraulic connection along strike within the basement rocks. This model results in separate groundwater sub catchments with limited or no groundwater through flow. This model is supported by evidence of the flat and stepped nature of mineral exploration water levels between each identified designated groundwater sub catchment.

The uncertainties associated with the conceptual model are as follows;

- the locations of all dolerite dykes and their properties that likely partition groundwater sub catchments are not known,
- the occurrence of strike-slip faults that may lead to juxtaposition of permeable horizons from the Brockman Iron Formation against the Wittenoom Formation, resulting in the potential for hydraulic connection with unforeseen impacts on the dewatering required or extent of drawdown,
- the extent of saturated alluvial cover that allows for flow between sub catchments above the dolerite dykes, and
- the amount of recharge that can occur to a compartmentalised system is considered by Golder to be practically negligible if groundwater levels are constant (i.e. in steady state) as there is negligible through flow expected across aquitards. Recharge has been applied to the model where loss from the groundwater system is attributed to groundwater dependent vegetation assemblages.

The numerical model was found to be most sensitive to the hydraulic conductivity of the dolerite dyke structures indicating that any changes in assumptions of these low permeability horizons significantly impacted the steady state calibration and water balance, lending support to the above model.

These uncertainties can be reduced in time with ongoing groundwater level monitoring and a campaign to install monitoring bores well away from pit areas, with the explicit purpose of understanding the regional hydrogeological context rather than investigations on the ore body as a focus. For example, monitoring bores placed either side of conceptualised no flow structures (dolerite dykes or strata bounding members) would likely indicate the amount of through flow occurring in response to stresses such as test pumping and/or mine dewatering.

5.4.2 Numerical Groundwater Model

The numerical model is the mathematical approximation of the above conceptual model. As such, it contains the same uncertainty associated with the conceptual model above, with the additional uncertainty associated with parameterisation of the aquifer units. The steady state calibration and water balance model results were largely insensitive to perturbation in the aquifer hydraulic conductivity and storage parameters (steady state models do not include a storage function as they assume the hydrogeological system is effectively in balance; that is, there is no change in the groundwater stored).

Sensitivity to hydraulic conductivity was reported in Golder (2017b). Given the conceptual model comprises isolated groundwater sub catchments the model results are relatively insensitive to changes to the hydraulic conductivity of the main aquifers, but was sensitive to changes in conductance of the dolerite dyke low permeability structures that isolate each sub catchment. As such, changes to the hydraulic conductivity of the aquifers does not overly influence the predicted mine water balance. Increasing the hydraulic conductivity reduces the time required to dewater a mine void, whereas reducing the hydraulic conductivity increases the time for effective dewatering and increase the number of bores required, but changes to the hydraulic conductivity do not impact the overall water balance.

The transient (time variant) numerical model predictions for dewatering are very sensitive (change significantly) to perturbations in storage parameters significantly impacting the predicted volume of dewatering required. This creates uncertainty with respect to the dewatering allocation to apply for and the



amount of water available for supply and or to be managed for disposal. Uncertainty in storage parameters does not overly impact the extent or amount of draw down associated with dewatering, as the mine plans will dictate to what depth dewatering is required. However it will impact the dewatering volumes required to achieve BWT mining and the drawdown associated with large water supply borefields if they are required to be established to mitigate a water deficit.

These uncertainties are only reduced in time with large scale stresses (dewatering) and ongoing monitoring of groundwater level responses to dewatering.

The rate and amount of post mining groundwater level recovery will be sensitive to the amount of groundwater recharge occurring to aquifers across the project area. The amount of groundwater recharge and its relationship to rainfall factors (rainfall frequency, duration and volume) is difficult to predict with the currently limited dataset and therefore there remains uncertainty over the extrapolation of groundwater level recovery curves post closure (i.e. out to 2136).

Given the compartmentalised nature of the groundwater system in the Project area, with sufficient groundwater recharge ratio and rainfall patterns, it is plausible (however considered unlikely) that groundwater levels in individual groundwater sub catchments could continue to rise steadily over time. This rise would only be limited to the overtopping point of each sub-catchment which could consist of shallow and conductive alluvium along which groundwater flow could occur across catchment. Alternatively there could be some restriction of groundwater level rise within sub catchments as a result of evapotranspiration occurring from vegetation uptake in the event that groundwater levels reach near surface.

Alternatively, the ratio of rainfall to groundwater recharge could be much lower than predicted by the model and in this case the recovery of groundwater levels may be much more subdued than estimated in this study. It is not possible to refine the relationship between groundwater levels and long term climate factors since monitoring data for the site is limited over a fairly short period (< 2 years).

5.4.3 Analytical Pit Water and Salt Balance

The analytical water balances are limited to the range in depth and volume provided by the pit shell designs. The analytical models for the groundwater and groundwater – surface water dependent mine voids commence with the assumption that groundwater has recovered to the minimum mine bench relative level. The time required for groundwater levels to recover are not included in the summary of time until steady state is reached. In the case of Westend the time for groundwater level recovery to the base of the minimum bench level is probably not significant given the considerable depth below water table and the large groundwater catchment associated with this pit, however this may not be the case for mine voids within the valley.

Analytical mine void water balances assume horizontal groundwater flow based on the Dupuit-Thiem equation. As such the groundwater input/outflow to the mine void balance commences once the water level in the mine void is greater than the final pit minimum bench.

The head dependent boundary condition for each individual catchment is fixed in time within the analytical water balances. In reality, enhanced recharge as a result of creek capture and storage could result in a change (increase) in these boundary conditions and recharge inputs, particularly where the mine void is a significant proportion of the groundwater sub catchment and surface water catchments are large in comparison. Similarly, ongoing evaporative losses in a groundwater dependent pit void may result in a negative change (decrease) in the boundary condition.

The post mining surface water catchment areas for the mine voids represented in the analytical models have been provided by Fortescue. There is significant uncertainty in the catchment run-off variables for determining the contribution of catchment run-off to the mine voids. The baseline runoff variables applied equated to those generated from the CSIRO Pilbara water resource assessment for the Ashburton Robe region (McFarlane, ed. 2015).

Whilst the chloride concentration in groundwater and rainfall is readily measurable, the variability in stream flow chloride concentration is likely to be highly variable and contingent on specific rainfall event intensity



and the antecedent catchment conditions (i.e. whether catchment was already wet or following a long dry period). The salt balances indicate that model predicted outcomes are very sensitive to catchment run-off chloride concentrations.

The salt balances assume that the input concentrations from surface water catchments and pit wall runoff are constant through time, where, as discussed above surface catchment runoff events might have different concentrations over time. Pit wall runoff is likely to be variable as well as different wall lithologies are exposed to evaporation and slowly covered by rising mine void water levels over time.

6.0 SUMMARY

Dewatering and water supply abstraction will be necessary to support the proposed Eliwana Mining Project. Groundwater level drawdown caused by the predicted dewatering of the Broadway East and Talisman pits is expected to be between 30 and 60 m beneath the length of the entire potential GDE's as shown in Figure 5D. Drawdown from dewatering at MM4-6 (Figure 5C) would occur adjacent to another potential mapped GDE, however the interpreted depth to water table likely precludes this area being groundwater dependent. Drawdown from water supply pumping, assuming worst case low generic specific yield and high demand scenario is in the order of 80 metres beneath potential GDE's identified in the Flying Fish area (Figure 5D).

Drawdown is not expected to extend beyond the compartmentalised aquifers indicated owing to the strata bound nature of the fractured rock environment and the numerous dolerite dykes and sills that occur across the Brockman syncline.

There is a potential worst-case surplus of project water, of up to 49 GL, for the life of the project. This value has been derived assuming an aggressive mining schedule between 2019 and 2024 where all pits are dewatered generating a surplus of water due to very high cumulative project dewatering rates (up to 500 L/s). It is possible that some of this surplus water could be retained within the project area through reinjection into groundwater sub catchments where dewatering is not being carried out or those which are earmarked for use for groundwater supply abstraction later in the mine life. Alternative surplus water management options should be considered and could comprise discharge of surplus project water to the surface water catchments, or with changes to the mine planning sequence, storage of surplus water to mined out voids.

During operations there is negligible opportunity to impact other groundwater users owing to the distance between mining operations and the strata-bound aquifer behaviour limiting across strike impacts. If any pastoral bores lie within the mining footprint there would be potential to impact their viability for water supply in the long term.

Cumulative impacts to groundwater are likely to comprise additional depletion of stored paleo groundwater within the Brockman Syncline and the potential for mixing of discharged surplus water in either the Boolgeeda or Duck Creek tributaries.

Due to the compartmentalised nature of the groundwater system, the recovery of groundwater levels post closure is predicted to be heavily influenced by the amount of groundwater level drawdown (or storage depletion) caused by dewatering and water supply abstraction. In all cases where dewatering or water supply is proposed during the Project's mine life, groundwater levels at the cessation of dewatering / water supply operations are predicted to be lower than pre-mining levels (up to 150 m at the proposed Westend mine void). The variability of groundwater level drawdown predicted results primarily from varying volumes of groundwater abstraction and internal groundwater sub catchment storage.

Groundwater level recovery is anticipated in the post closure period, assuming some modern recharge is occurring within the valley floor between the Brockman Iron Formation and lower Marra Mamba Iron Formation hills. This recovery may be aided by the capture and storage of surface water runoff within some of the mine voids over time. A range of mine void lake types could form post closure, including:

- Groundwater dependent mine void lakes (Westend and Westside, and potentially Talisman, Broadway West, MM4-6 and Eagles Nest)
- Groundwater – Surface water mine voids (potentially Talisman, Broadway West, Eagle's Nest and MM4-6)



- Surface water dependent mine voids (other AWT pits within the valley that capture surface water run-off from catchments greater than the mine void pit crest area)

Following mine closure, the general change in land forms comprising open cut pits will result in a combination of scattered perennial and ephemeral mine void lakes along the northern limb of the Brockman Syncline from the east of Nammuldi to the west of the Project for a distance of ~75km.

The mine void lake water quality has been assessed on the basis of an evaporative concentration of chloride within the mine void (pit) lakes. The only mine voids that are likely to eventually become saline are the groundwater dependent mine voids that receive negligible surface water runoff from a greater catchment. The time until these mine voids become saline (Chloride >2,500 mg/L) is predicted to be in the order 600+ years.

7.0 IMPORTANT INFORMATION

Your attention is drawn to the document titled – “Important Information Relating to this Report”, which is included in Appendix E of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

8.0 REFERENCES

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Report Signature Page

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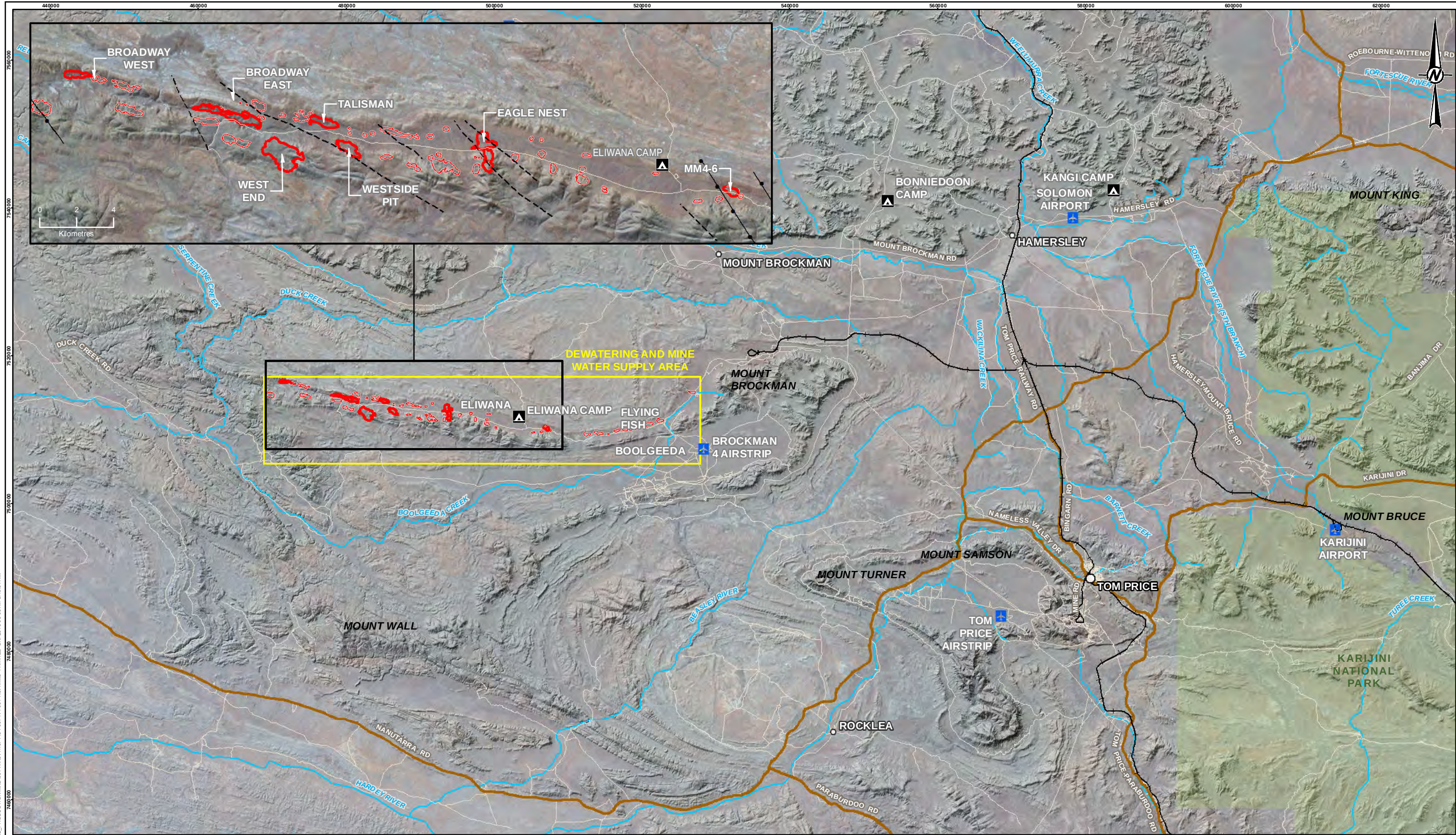
Wade Dodson
Principal Hydrogeologist

MJB/AP/mjb

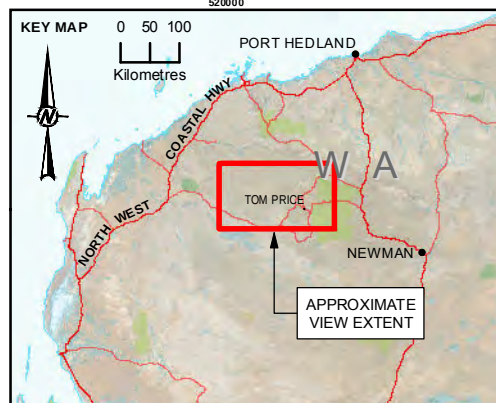
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- LEGEND**
- PIT SHELL BELOW GROUNDWATER TABLE
 - PIT SHELL
 - CAMP SITE
 - AIRPORT / AIRSTRIIP
 - EXISTING RAIL
 - MAIN ROAD
 - ACCESS ROAD / TRACK
 - DRAINAGE



CLIENT
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CONSULTANT



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DESIGNED	MJB
PREPARED	MS
REVIEWED	MJB
APPROVED	MJB

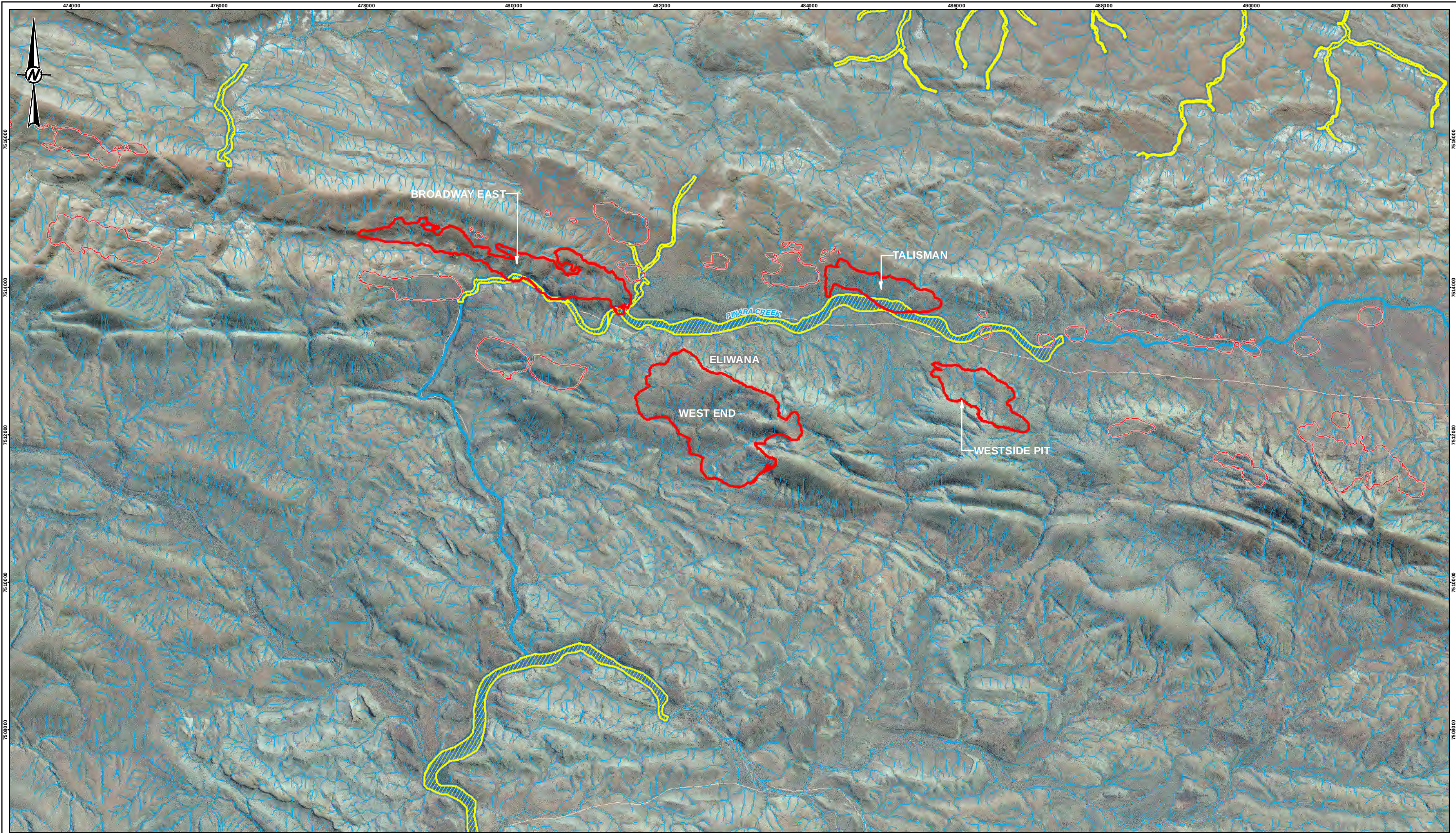
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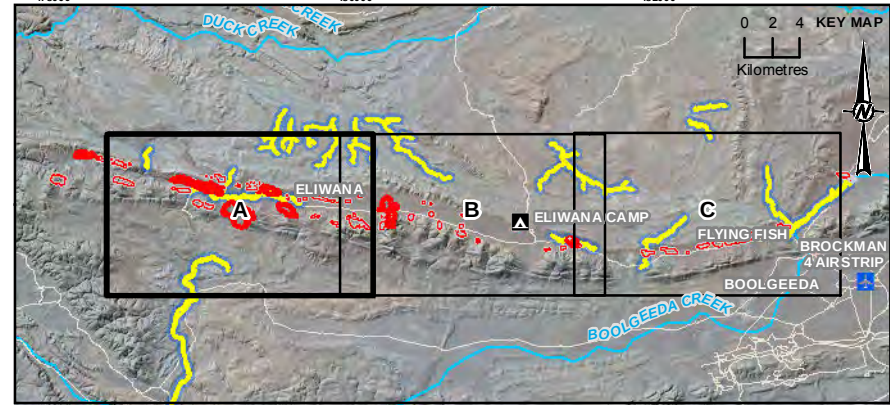
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ELIWANA MINING PROJECT - GROUNDWATER IMPACT ASSESSMENT

TITLE
PROPOSED ELIWANA MINING PROJECT LOCATIONS

PROJECT NO.	CONTROL	REV.	FIGURE
1671484	007 R	4	1



- LEGEND**
- PIT SHELL BELOW GROUNDWATER TABLE
 - PIT SHELL
 - POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEM (GDE)
 - ACCESS ROAD / TRACK
 - DRAINAGE



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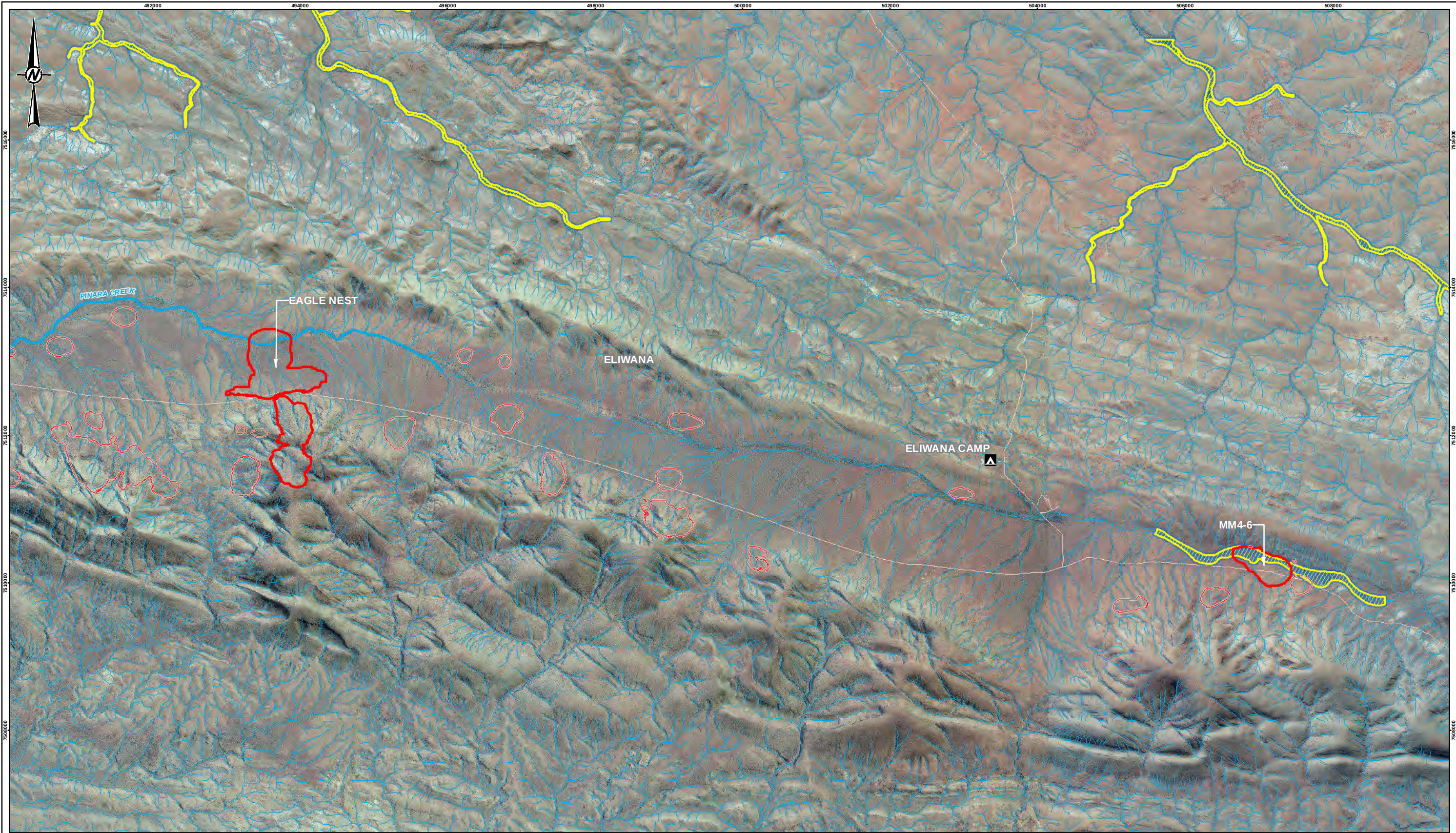
PROJECT
ELIWANA MINING PROJECT - GROUNDWATER IMPACT ASSESSMENT

TITLE
POTENTIAL GROUNDWATER DEPENDENT VEGETATION ASSEMBLAGES

PROJECT NO.	CONTROL	REV.	FIGURE
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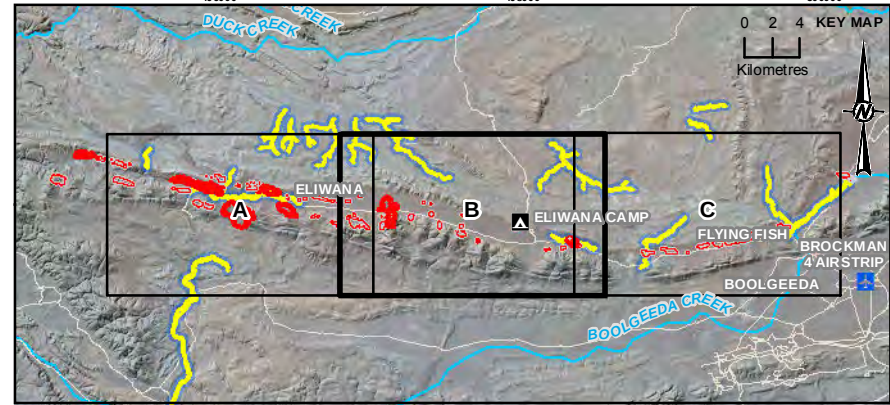
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LEGEND

- PIT SHELL BELOW GROUNDWATER TABLE
- PIT SHELL
- POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEM (GDE)
- CAMP SITE
- ACCESS ROAD / TRACK
- DRAINAGE



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REVIEWED	MJB
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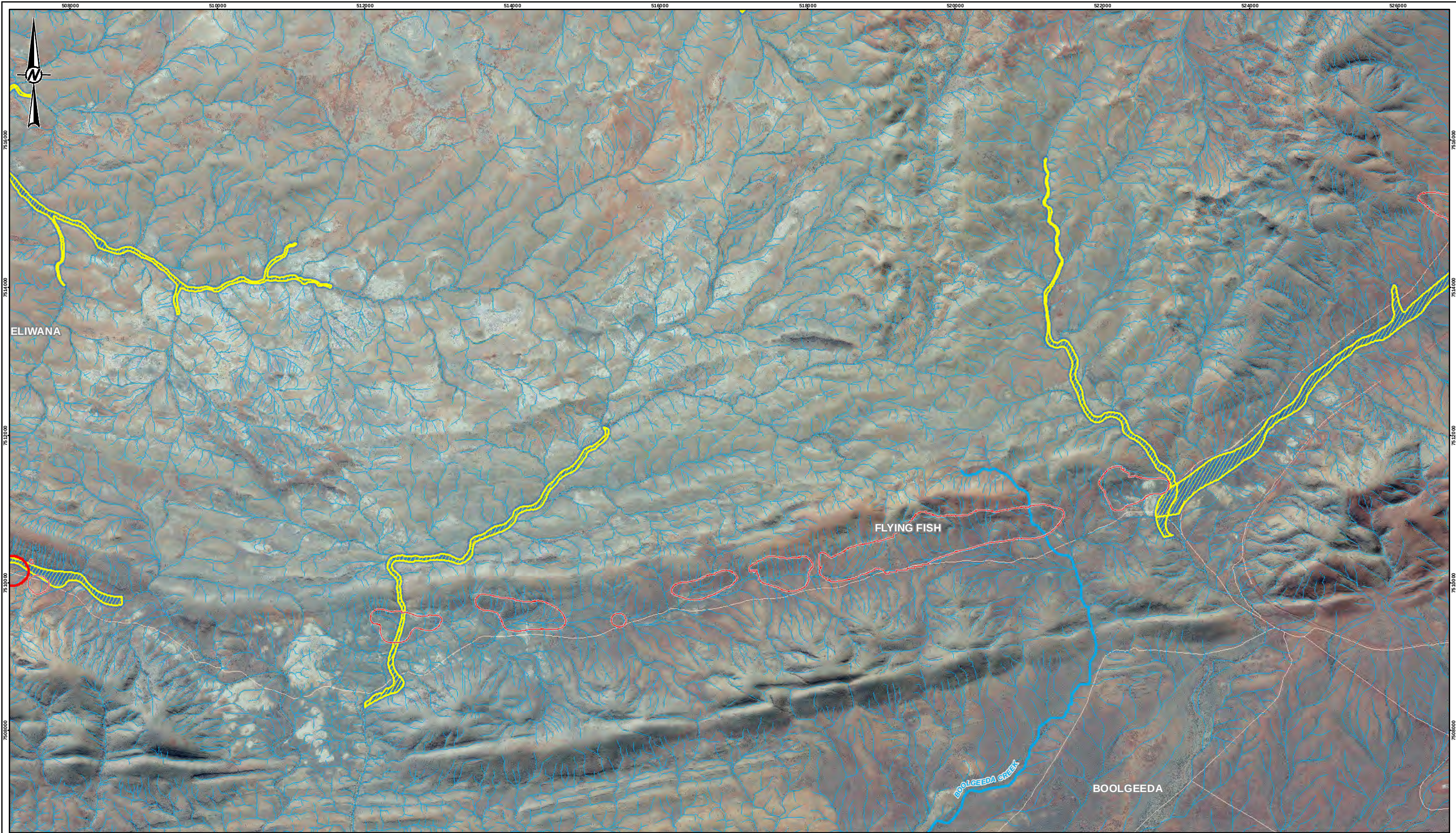
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ELIWANA MINING PROJECT - GROUNDWATER IMPACT ASSESSMENT

TITLE
POTENTIAL GROUNDWATER DEPENDENT VEGETATION ASSEMBLAGES

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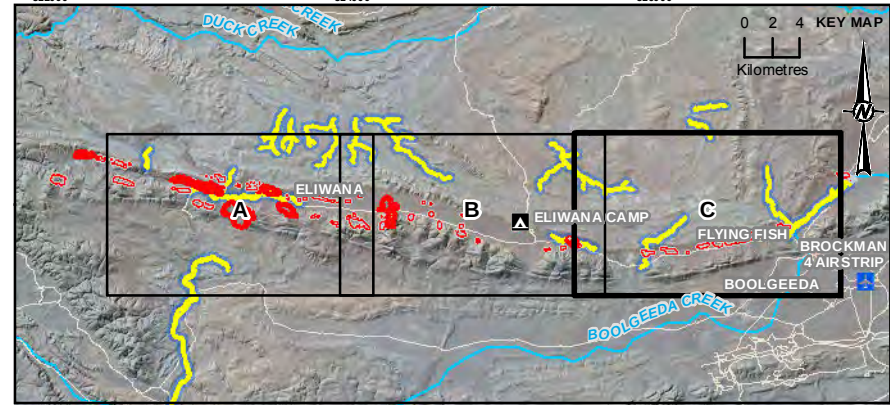
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LEGEND

- PIT SHELL BELOW GROUNDWATER TABLE
- PIT SHELL
- POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEM (GDE)
- ACCESS ROAD / TRACK
- DRAINAGE



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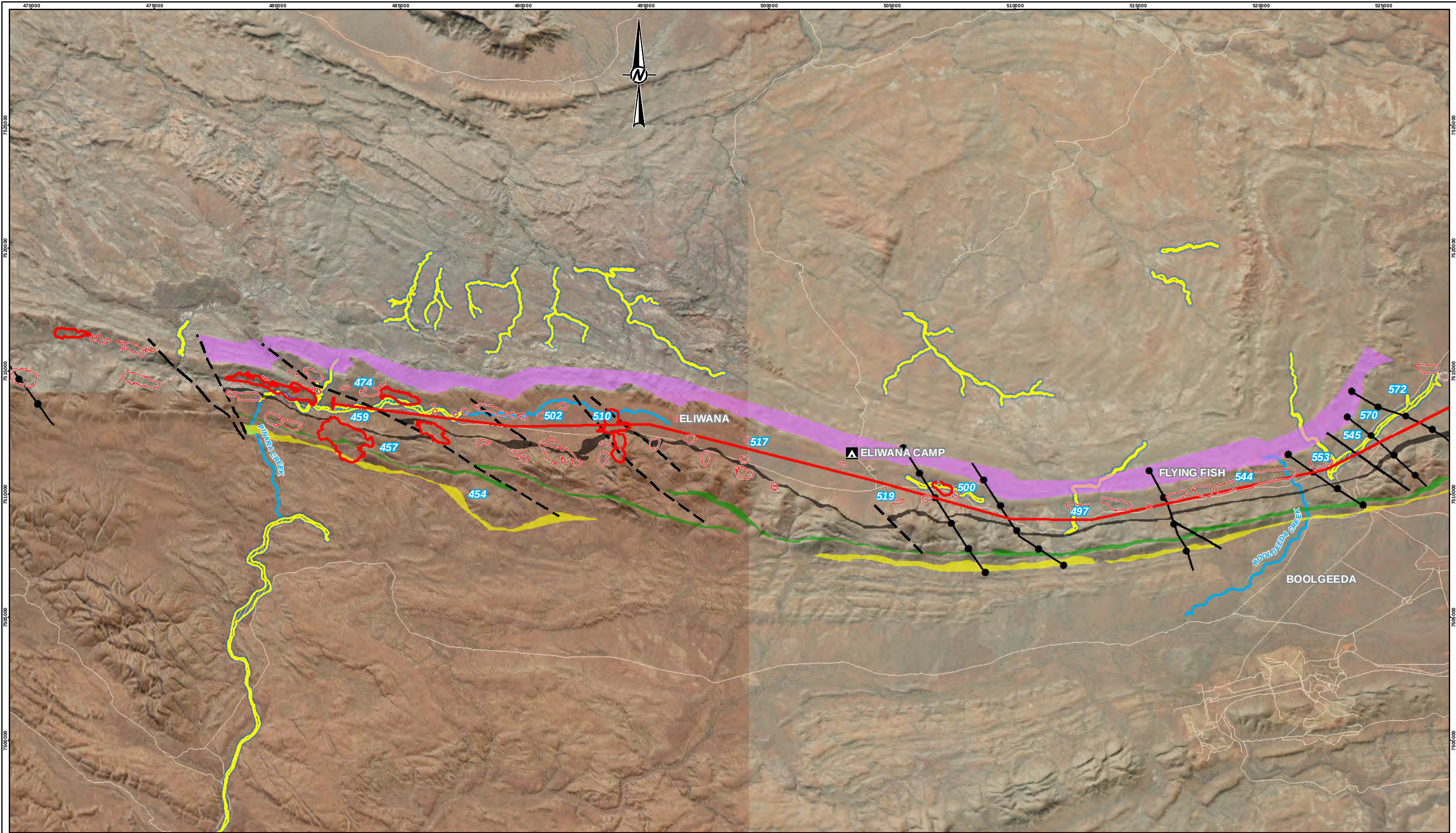
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ELIWANA MINING PROJECT - GROUNDWATER IMPACT ASSESSMENT

TITLE
POTENTIAL GROUNDWATER DEPENDENT VEGETATION ASSEMBLAGES

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- LEGEND**
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 - CAMP SITE
 - ACCESS ROAD / TRACK
 - MAJOR DRAINAGE
 - PIT SHELL BELOW GROUNDWATER TABLE
 - PIT SHELL
 - POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEM (GDE)
 - LONG SECTIONING LOCATION
 - INTERPRETED DYKE
 - INTERPRETED FAULT
 - DOLERITE SILL
 - JEERINAH FORMATION
 - MOUNT MCCRAE SHALE
 - YANDICOOGINA SHALE



CLIENT
FORTESCUE METALS GROUP

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	PREPARED	MS
	REVIEWED	MJB
	APPROVED	MJB



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1. COORDINATE SYSTEM: GDA 1994 MGA ZONE 50

REFERENCES:
1. AERIAL IMAGERY AND ROADS © WESTERN AUSTRALIAN LAND INFORMATION AUTHORITY TRADING AS LANDGATE (2018)
2. VEGETATION DATA MAPPING AND DRAINAGE SUPPLIED BY CLIENT
3. INSET IMAGE AND TOPOGRAPHY SOURCED FROM GEOSCIENCE AUSTRALIA

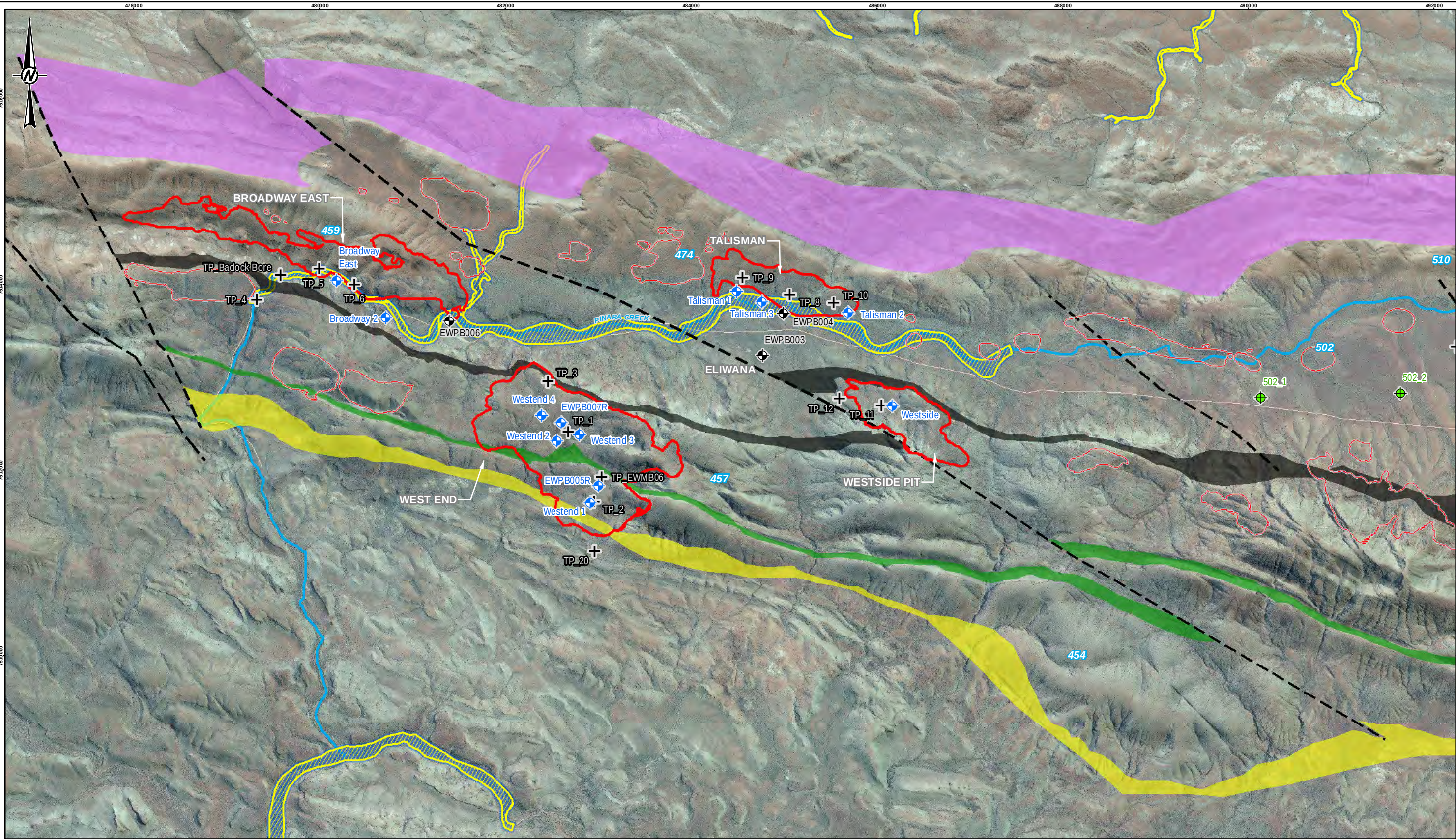
PROJECT
ELIWANA MINING PROJECT - GROUNDWATER IMPACT ASSESSMENT

TITLE
GROUNDWATER SUB CATCHMENTS

PROJECT NO. 1671484	CONTROL 007 R	REV. 4	FIGURE 3
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZES HAS BEEN MODIFIED FROM ISO/A3 25mm



LEGEND

473 INTERPRETED GROUNDWATER LEVEL (m AHD)

PROPOSED WATER SUPPLY BORE

EXISTING WATER SUPPLY BORE

PROPOSED DEWATERING BORE

EXISTING DEWATERING BORE

TRACKING POINT

PIT SHELL BELOW GROUNDWATER TABLE

PIT SHELL

CAMP SITE

ACCESS ROAD / TRACK

MAJOR DRAINAGE

INTERPRETED DYKE

INTERPRETED FAULT

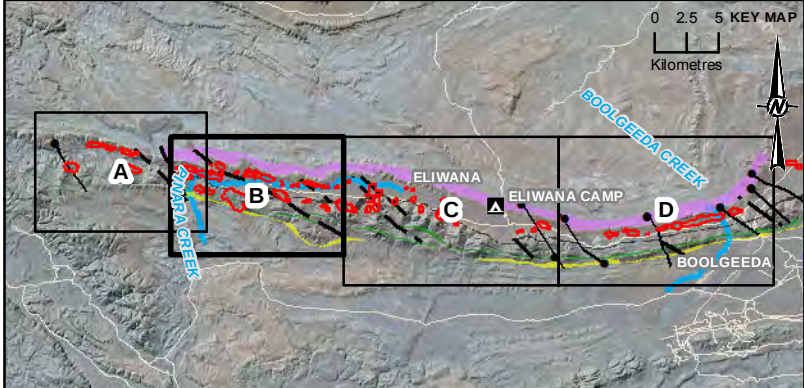
DOLERITE SILL

JEERINAH FORMATION

MOUNT MCCRAE SHALE

YANDICOOGINA SHALE

POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEM (GDE)



CLIENT
FORTESCUE METALS GROUP

CONSULTANT
 GOLDER

0 2.5 5 KEY MAP
Kilometres

0 1 2
KILOMETRES

1:40,000

YYYY-MM-DD	2018-06-08
DESIGNED	MJB
PREPARED	MS
REVIEWED	MJB
APPROVED	MJB

NOTE:
1. COORDINATE SYSTEM: GDA 1994 MGA ZONE 50

REFERENCES:
1. AERIAL IMAGERY AND ROADS © WESTERN AUSTRALIAN LAND INFORMATION AUTHORITY TRADING AS LANDGATE (2018)
2. VEGETATION DATA MAPPING AND DRAINAGE SUPPLIED BY CLIENT
3. INSET IMAGE AND TOPOGRAPHY SOURCED FROM GEOSCIENCE AUSTRALIA

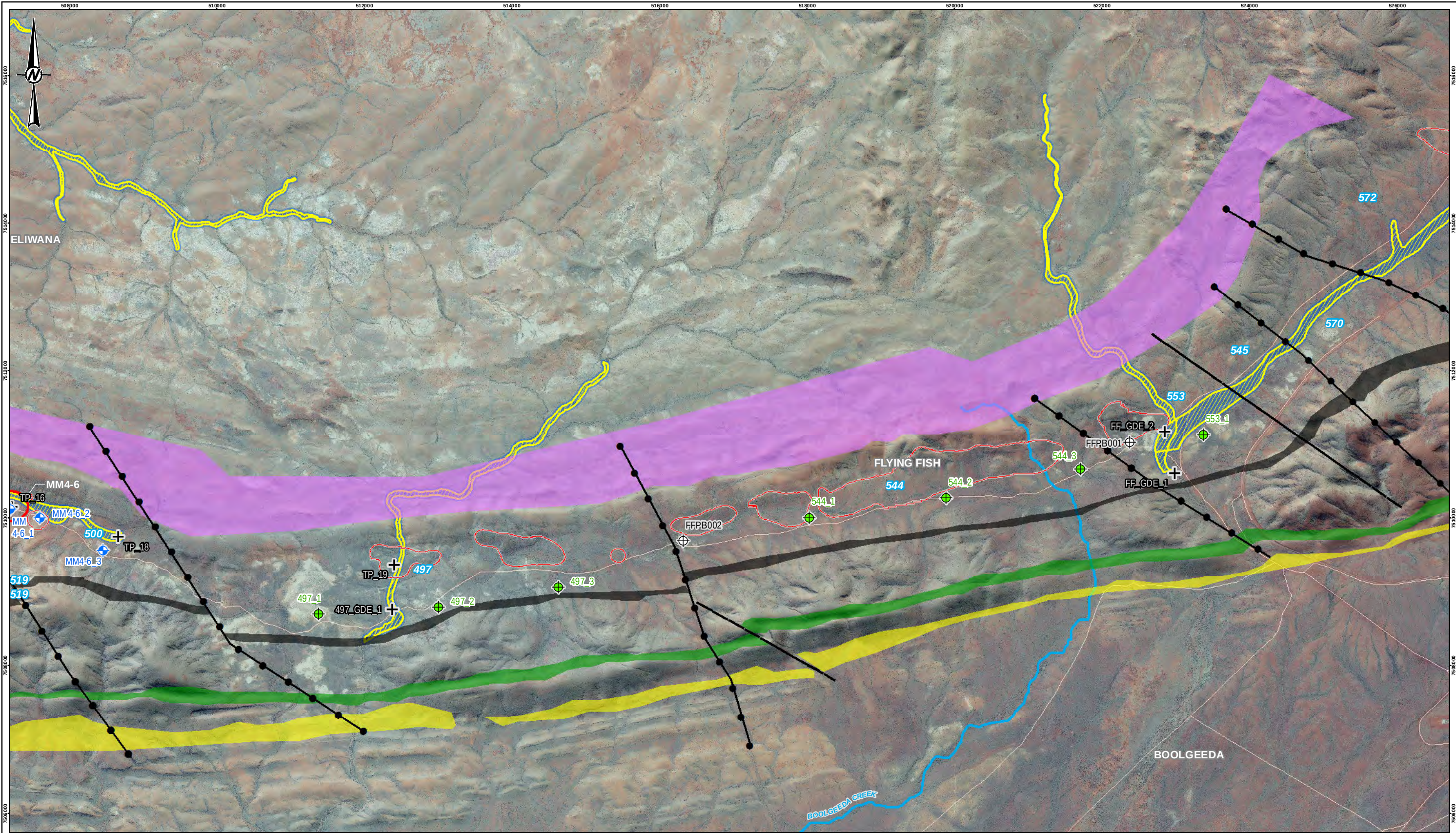
PROJECT
ELIWANA MINING PROJECT - GROUNDWATER IMPACT ASSESSMENT

TITLE
GROUNDWATER MODELLING LOCATIONS

PROJECT NO. 1671484	CONTROL 007 R	REV. 4	FIGURE 5B
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473

INTERPRETED GROUNDWATER LEVEL (m AHD)

PROPOSED WATER SUPPLY BORE

EXISTING WATER SUPPLY BORE

PROPOSED DEWATERING BORE

EXISTING DEWATERING BORE

TRACKING POINT

PIT SHELL BELOW GROUNDWATER TABLE

PIT SHELL

CAMP SITE

ACCESS ROAD / TRACK

MAJOR DRAINAGE

INTERPRETED DYKE

INTERPRETED FAULT

DOLERITE SILL

JEERINAH FORMATION

MOUNT MCCRAE SHALE

YANDICOOGINA SHALE

POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEM (GDE)

CLIENT

FORTESCUE METALS GROUP

CONSULTANT

YYYY-MM-DD

2018-06-08

DESIGNED

MJB

PREPARED

MS

REVIEWED

MJB

APPROVED

MJB

GOLDER

NOTE:

1. COORDINATE SYSTEM: GDA 1994 MGA ZONE 50

REFERENCES:

1. AERIAL IMAGERY AND ROADS © WESTERN AUSTRALIAN LAND INFORMATION AUTHORITY TRADING AS LANDGATE (2018)

2. VEGETATION DATA MAPPING AND DRAINAGE SUPPLIED BY CLIENT

3. INSET IMAGE AND TOPOGRAPHY SOURCED FROM GEOSCIENCE AUSTRALIA

PROJECT

ELIWANA MINING PROJECT - GROUNDWATER IMPACT ASSESSMENT

TITLE

GROUNDWATER MODELLING LOCATIONS

PROJECT NO.

1671484

CONTROL

007 R

REV.

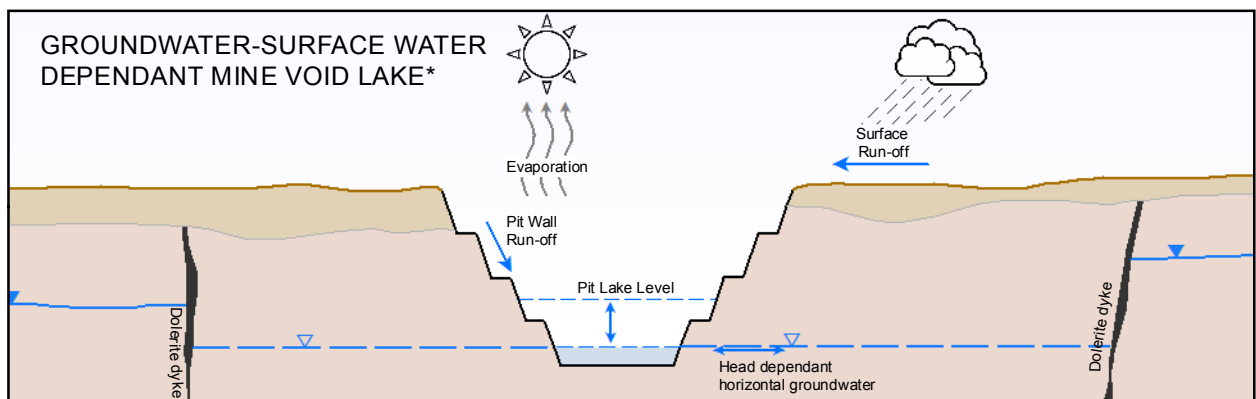
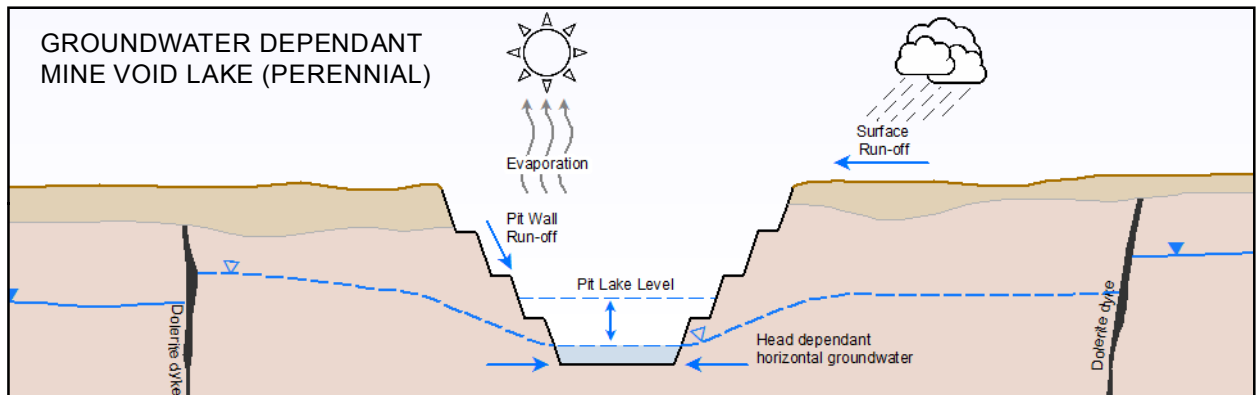
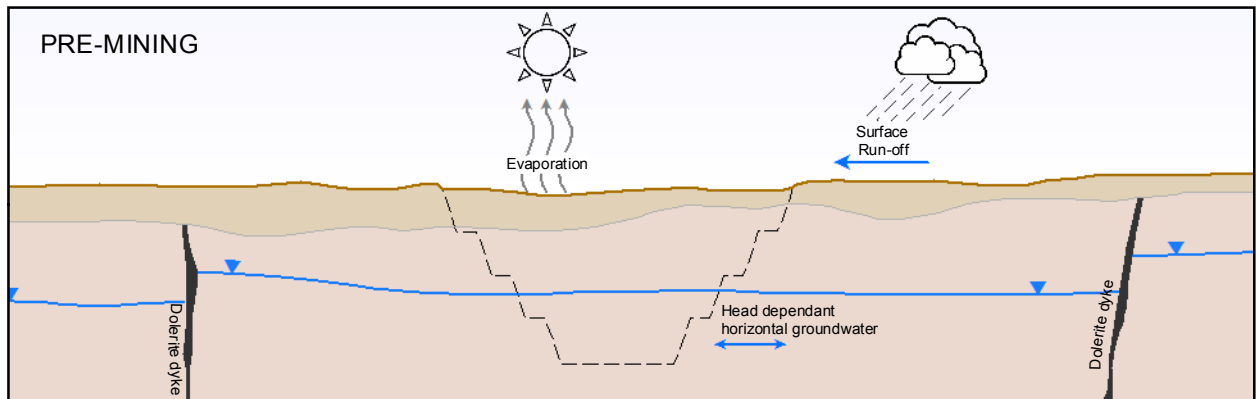
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FIGURE

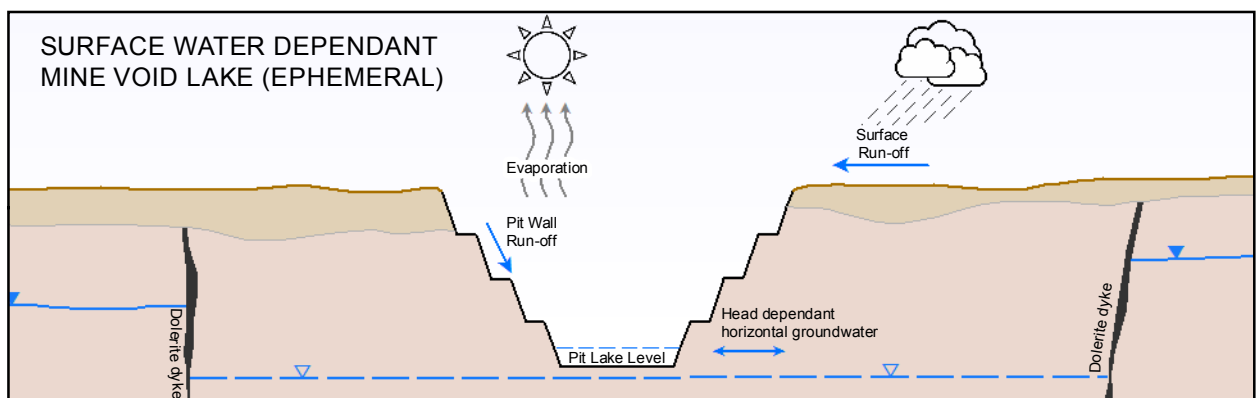
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* WHETHER PERENNIAL OR EPHEMERAL CRITICALLY DEPENDANT ON BOUNDARY HEAD CONDITION POST DEWATERING



CLIENT
FORTESCUE METALS GROUP

PROJECT
ELIWANA MINING PROJECT - GROUNDWATER IMPACT
ASSESSMENT

CONSULTANT



YYYY-MM-DD 2018-06-06

DESIGNED WD

PREPARED SR

REVIEWED WD

APPROVED WD

TITLE
CONCEPTUAL MINE VOID CLOSURE MODELS

PROJECT NO.
1671484

CONTROL
007 R

REV.
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FIGURE
6



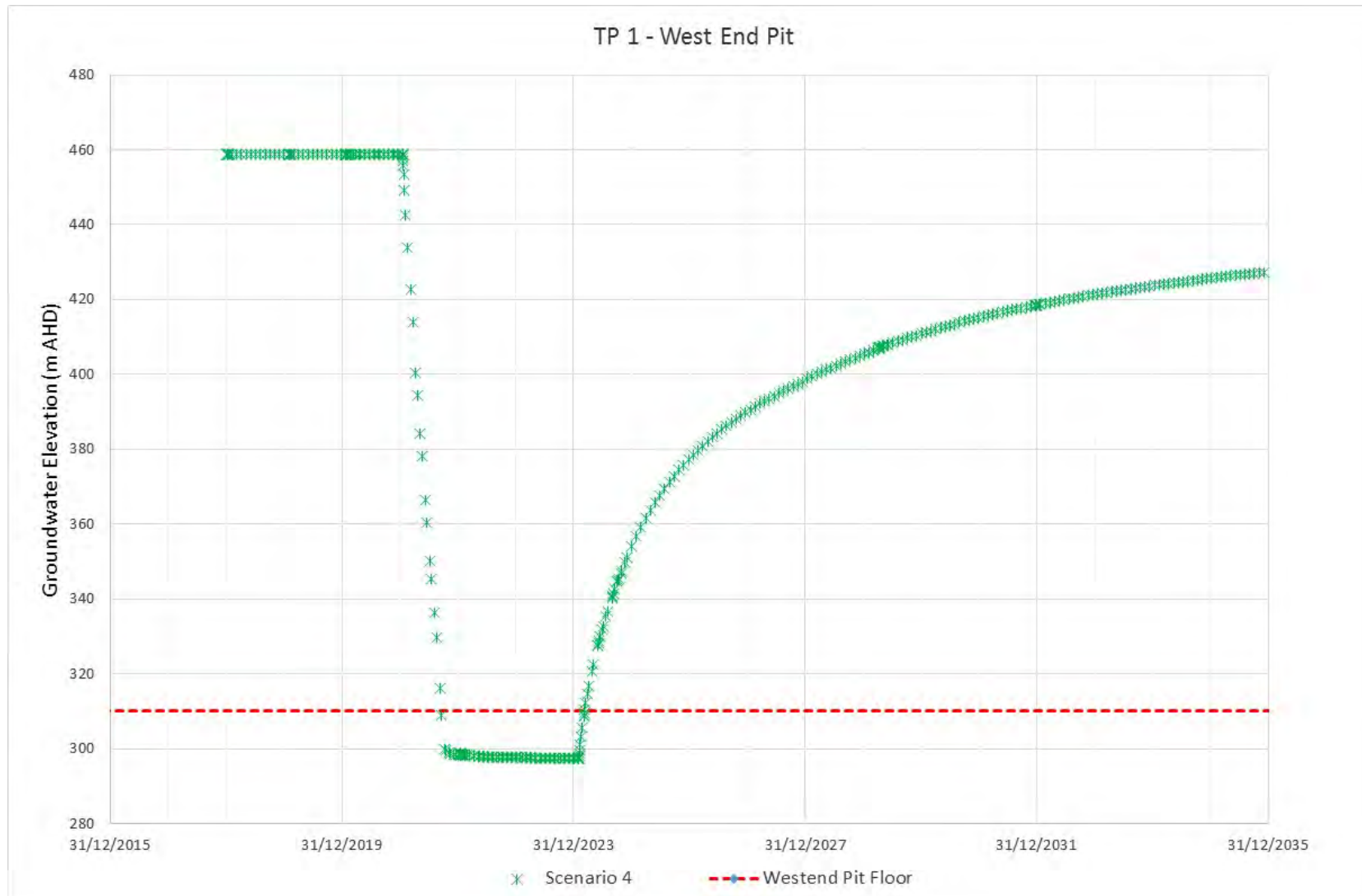
APPENDIX A

Groundwater Model Tracking Point Plots



APPENDIX A

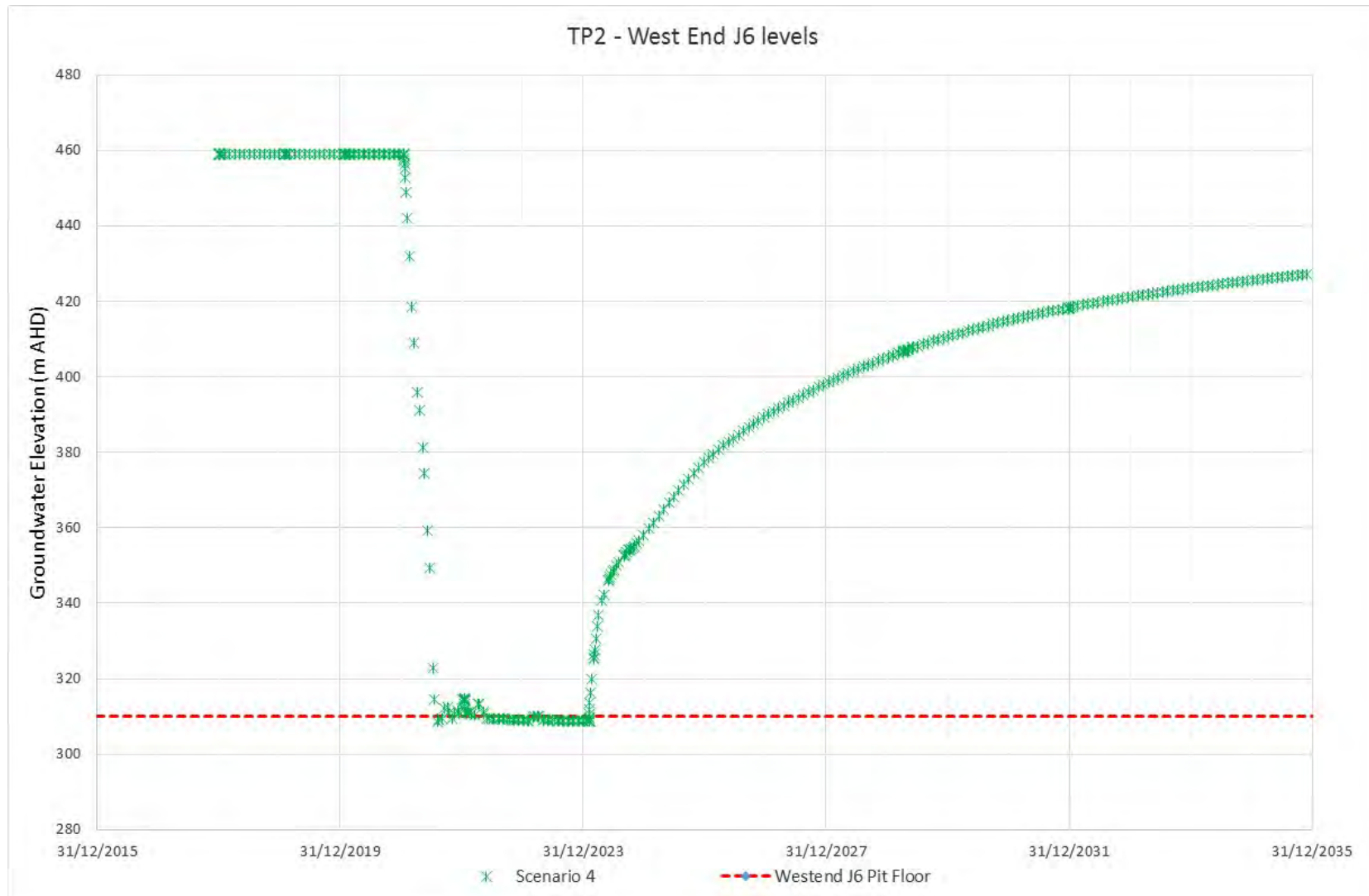
Groundwater Model Tracking Point Plots





APPENDIX A

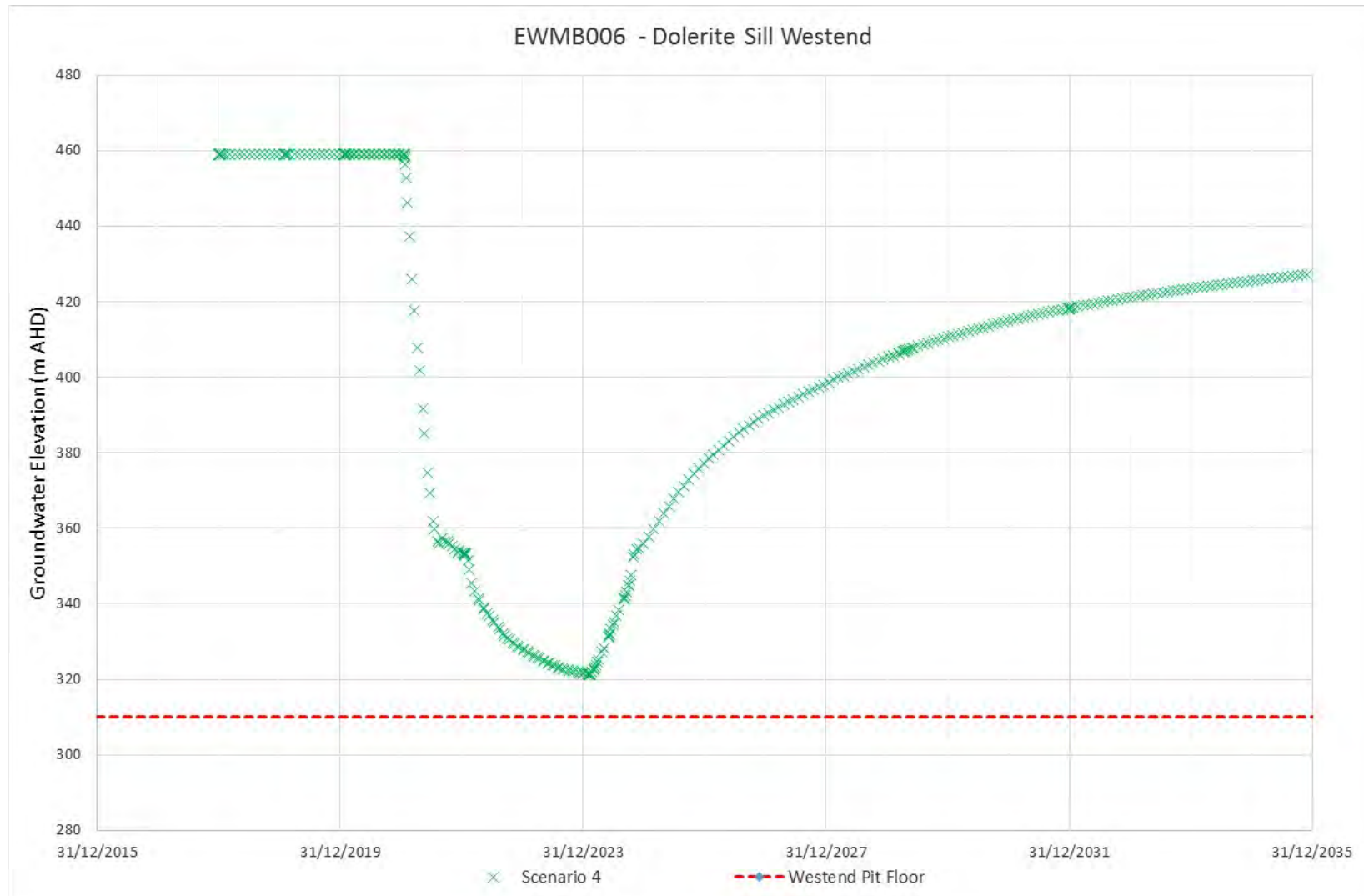
Groundwater Model Tracking Point Plots





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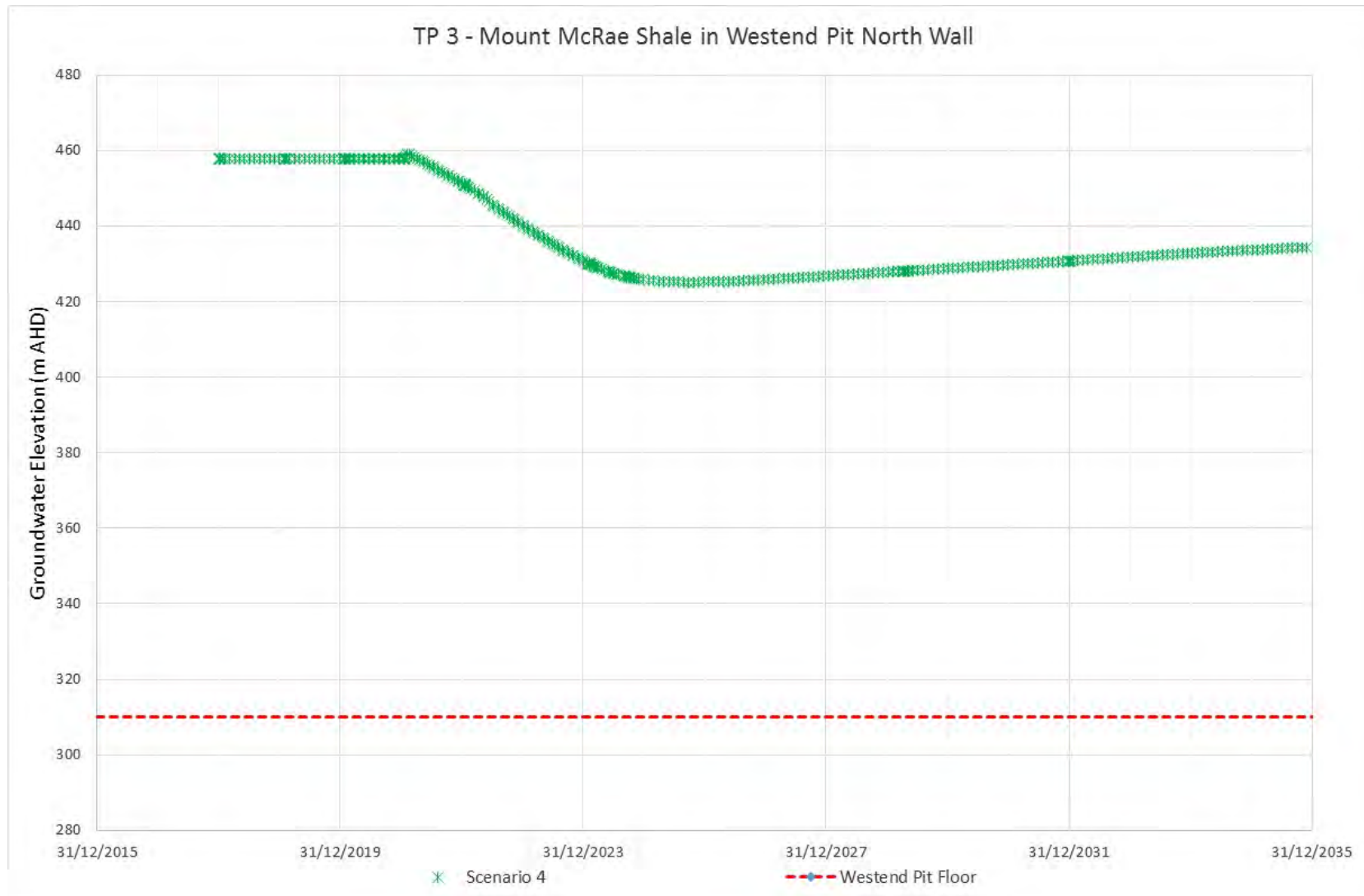
Groundwater Model Tracking Point Plots





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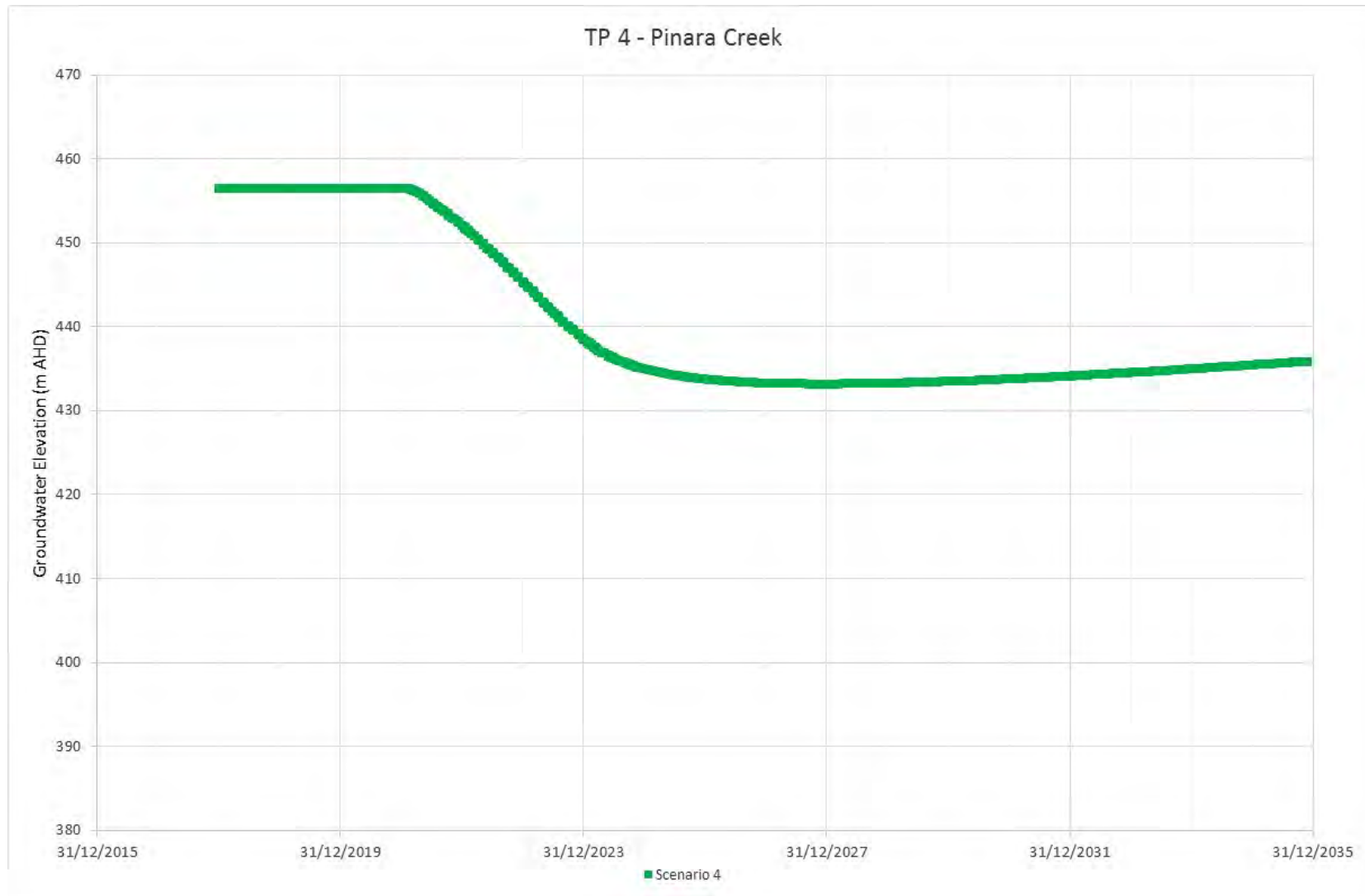
Groundwater Model Tracking Point Plots





APPENDIX A

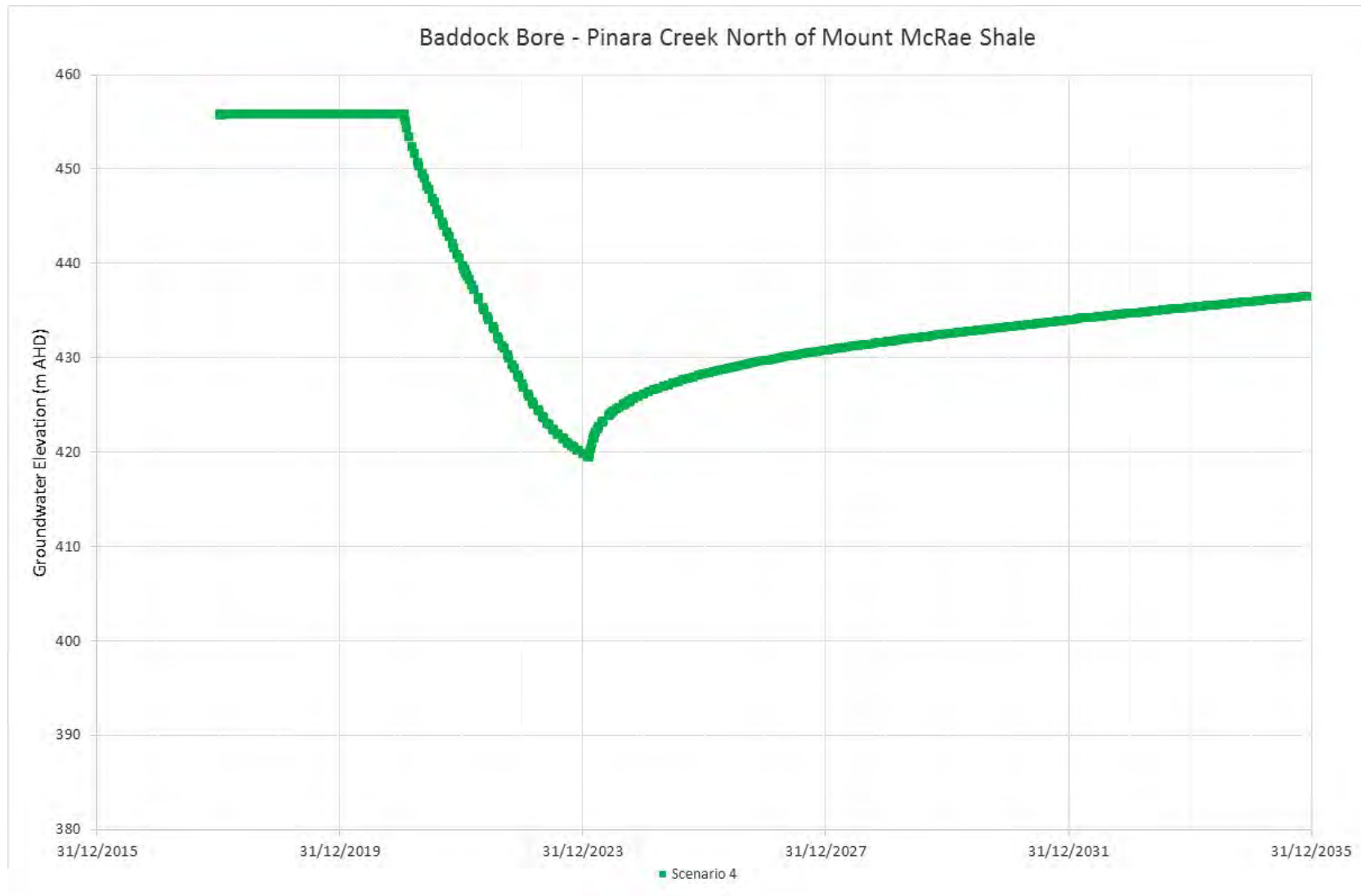
Groundwater Model Tracking Point Plots





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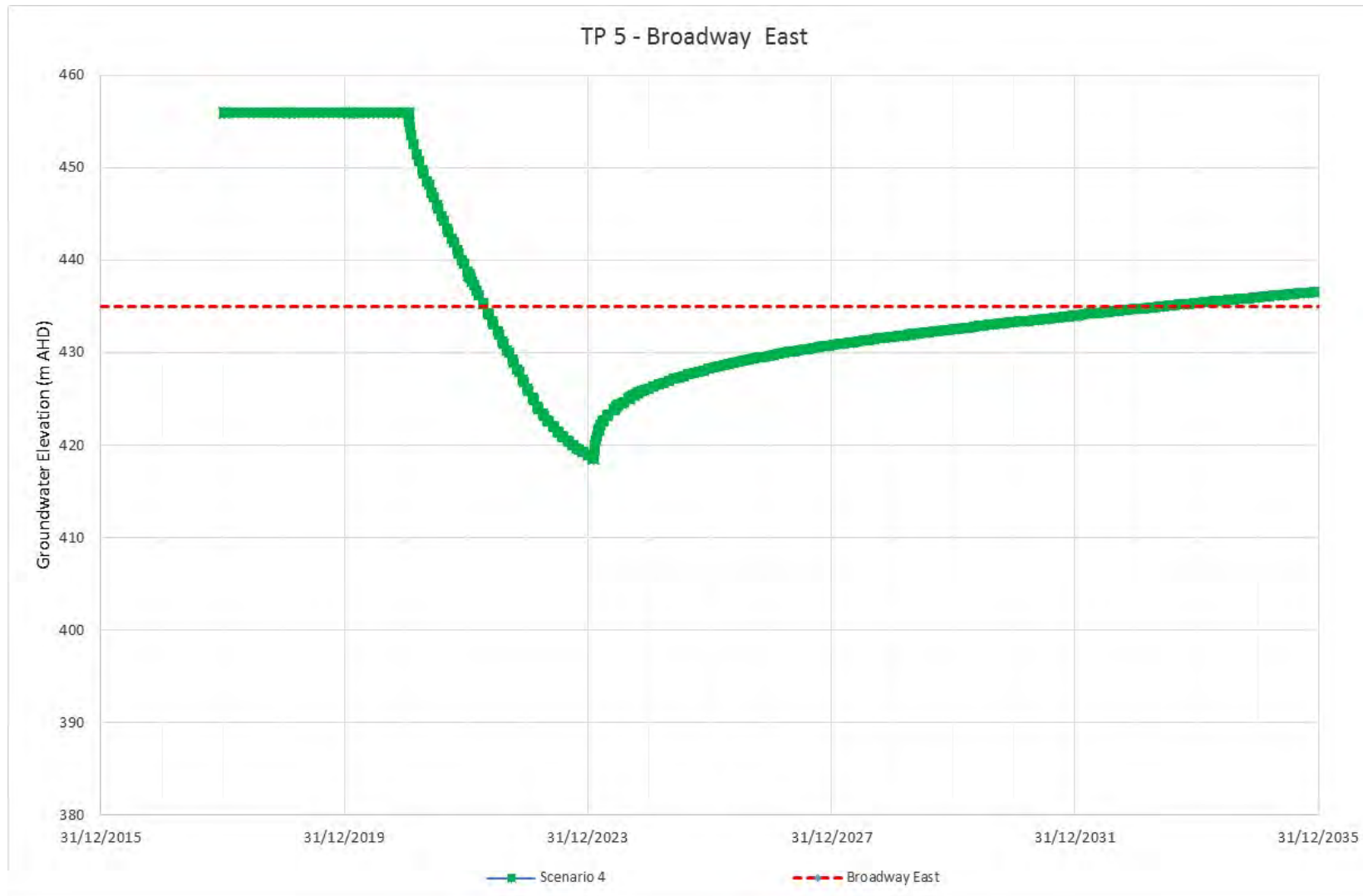
Groundwater Model Tracking Point Plots





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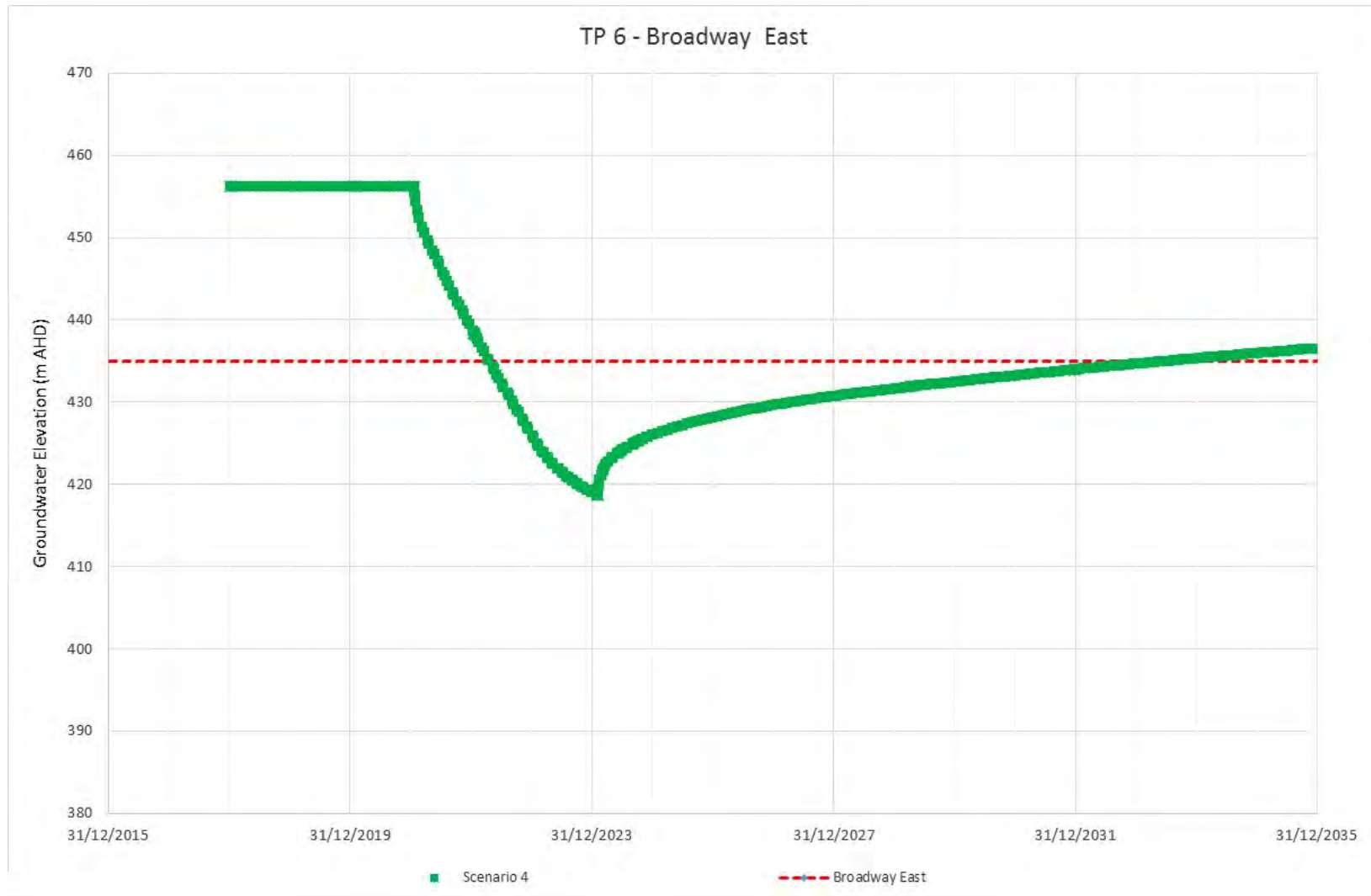
Groundwater Model Tracking Point Plots





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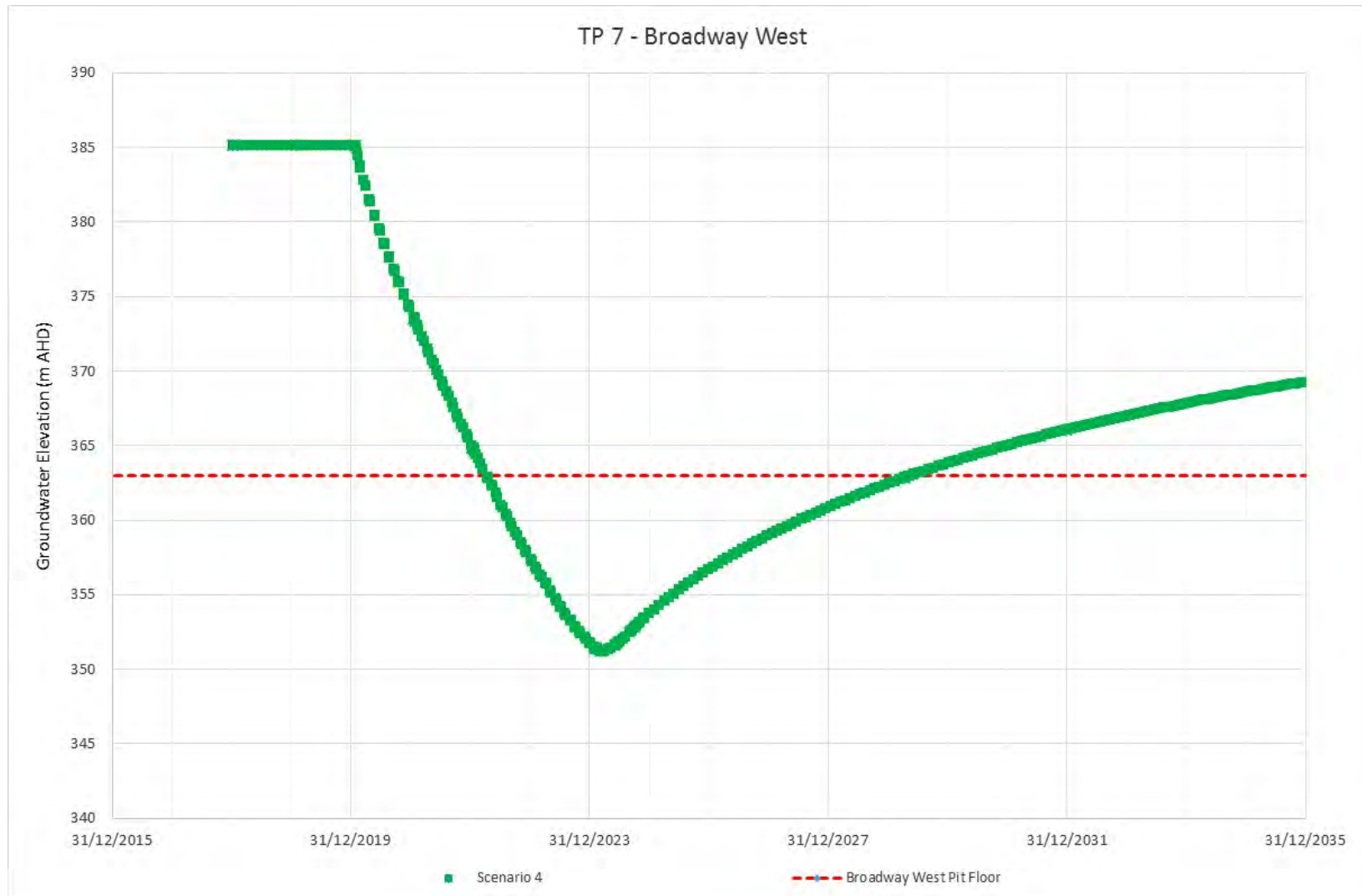
Groundwater Model Tracking Point Plots





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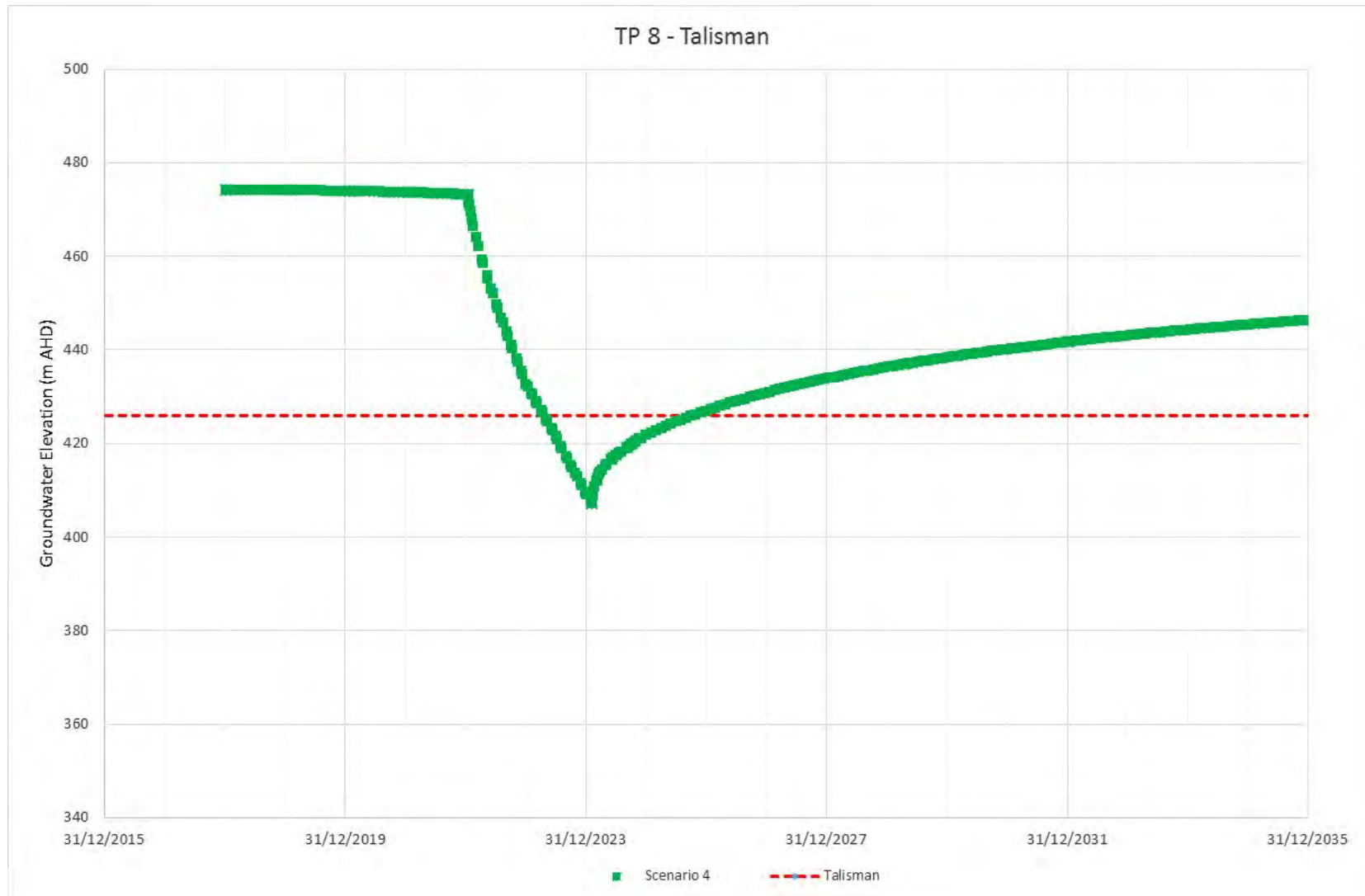
Groundwater Model Tracking Point Plots





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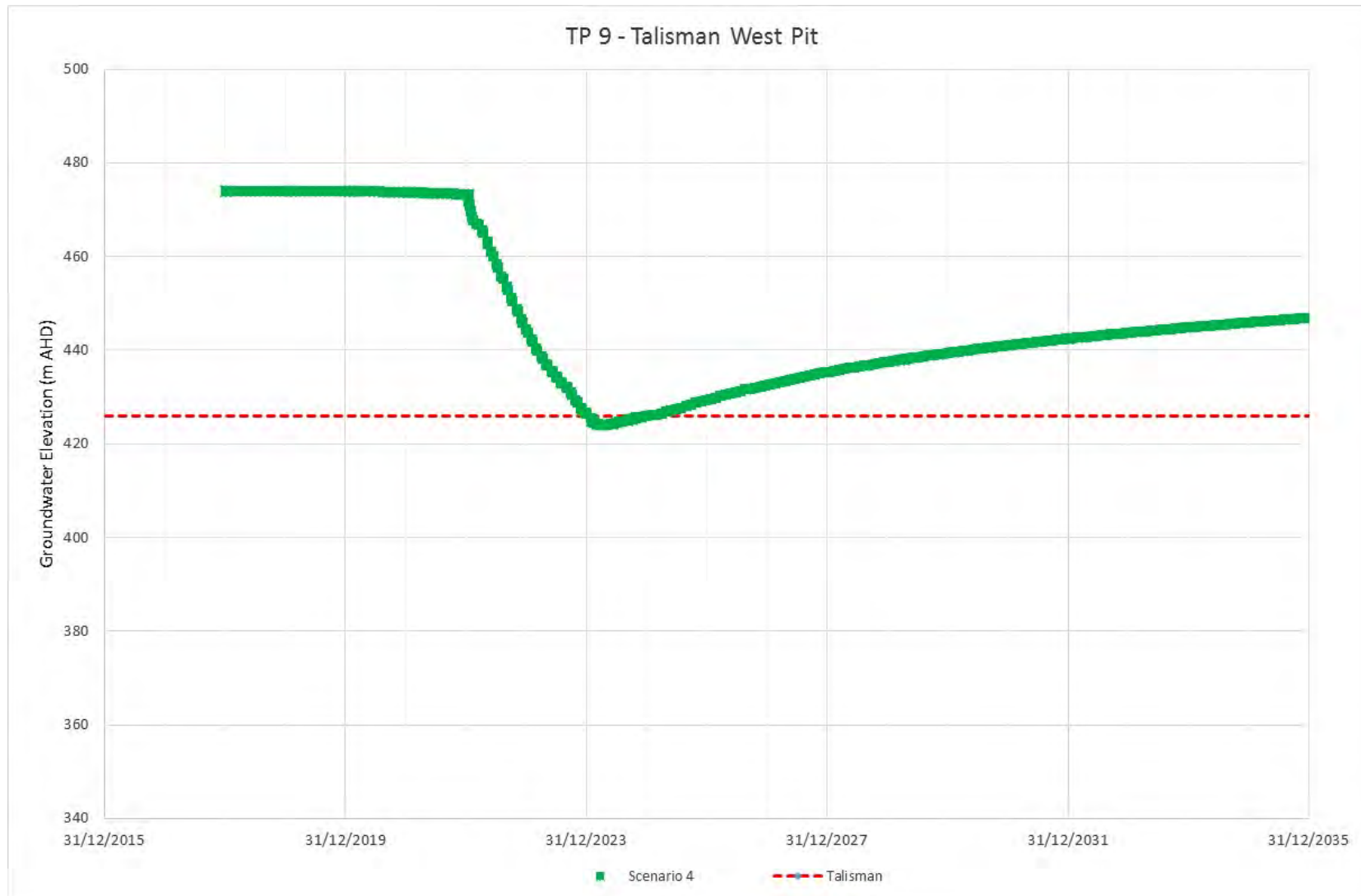
Groundwater Model Tracking Point Plots





APPENDIX A

Groundwater Model Tracking Point Plots





APPENDIX A

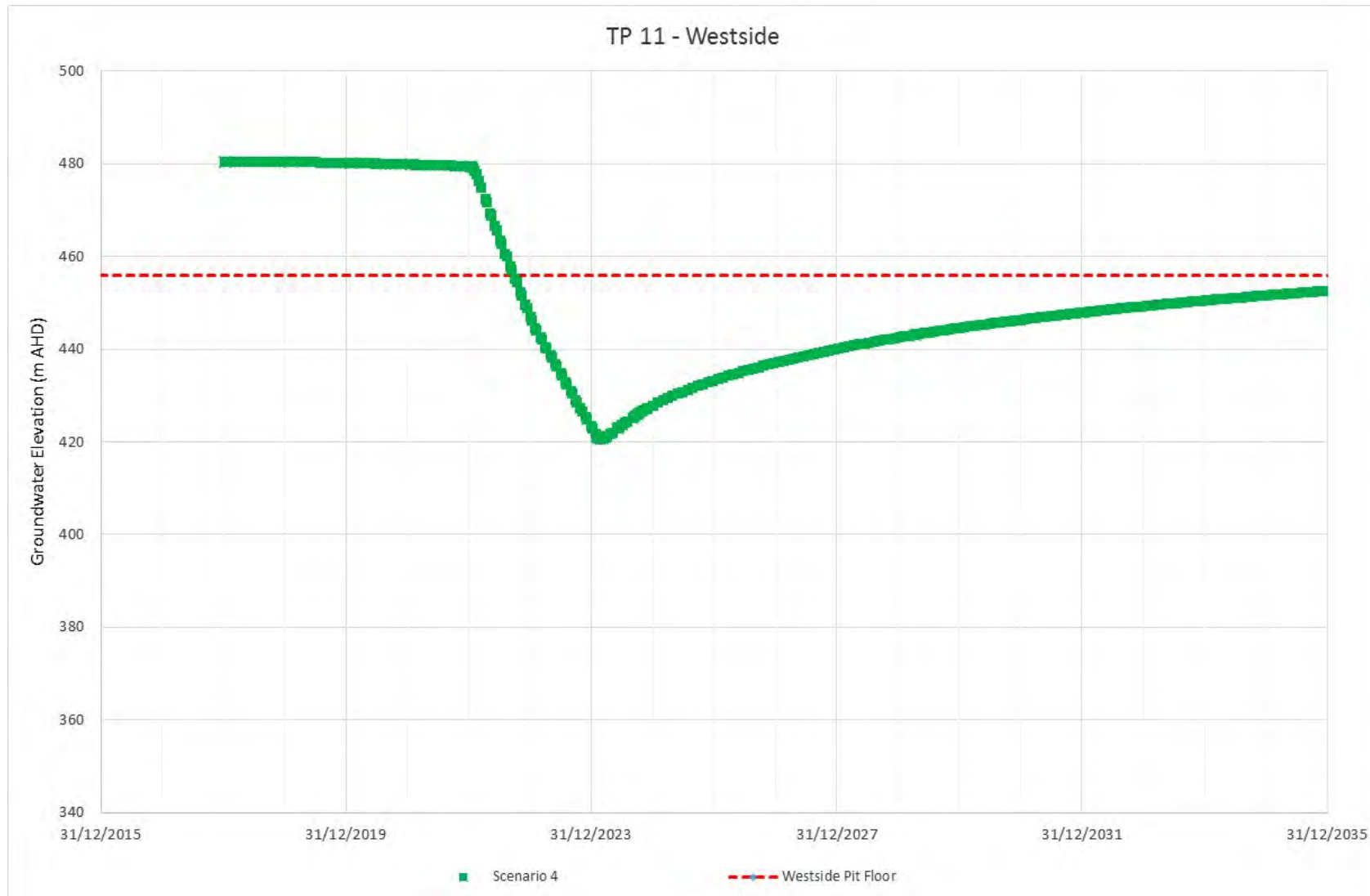
Groundwater Model Tracking Point Plots





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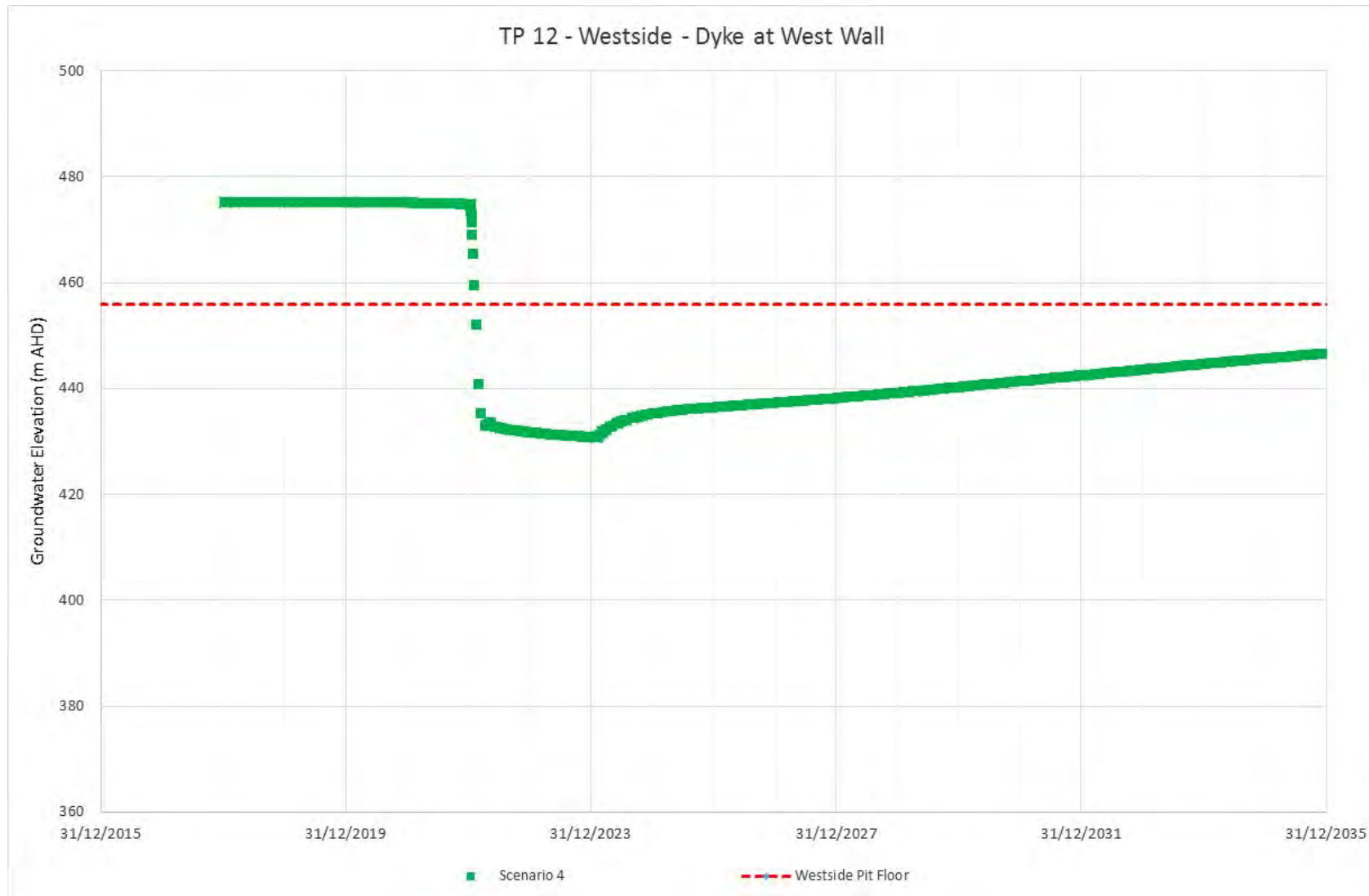
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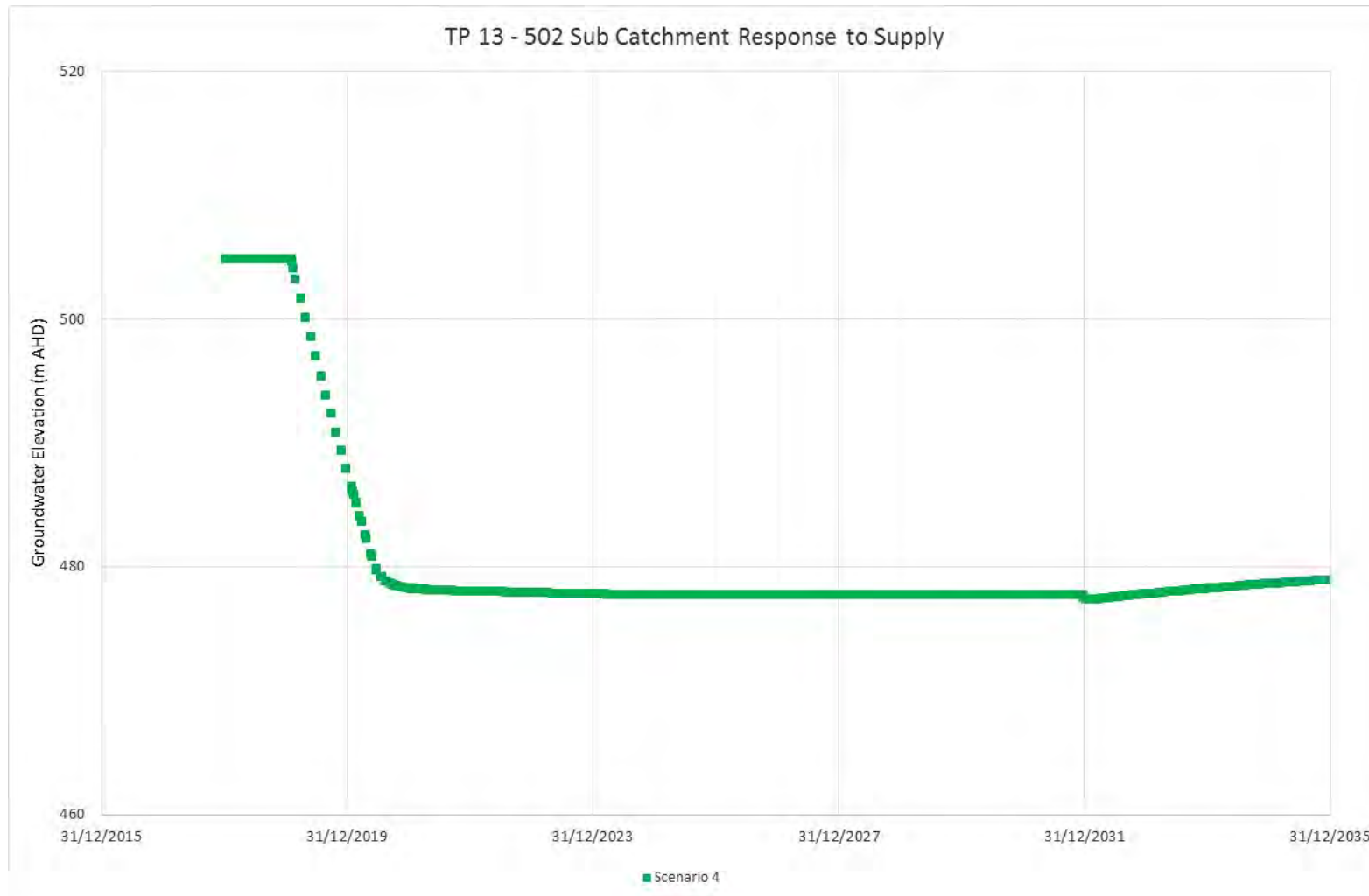
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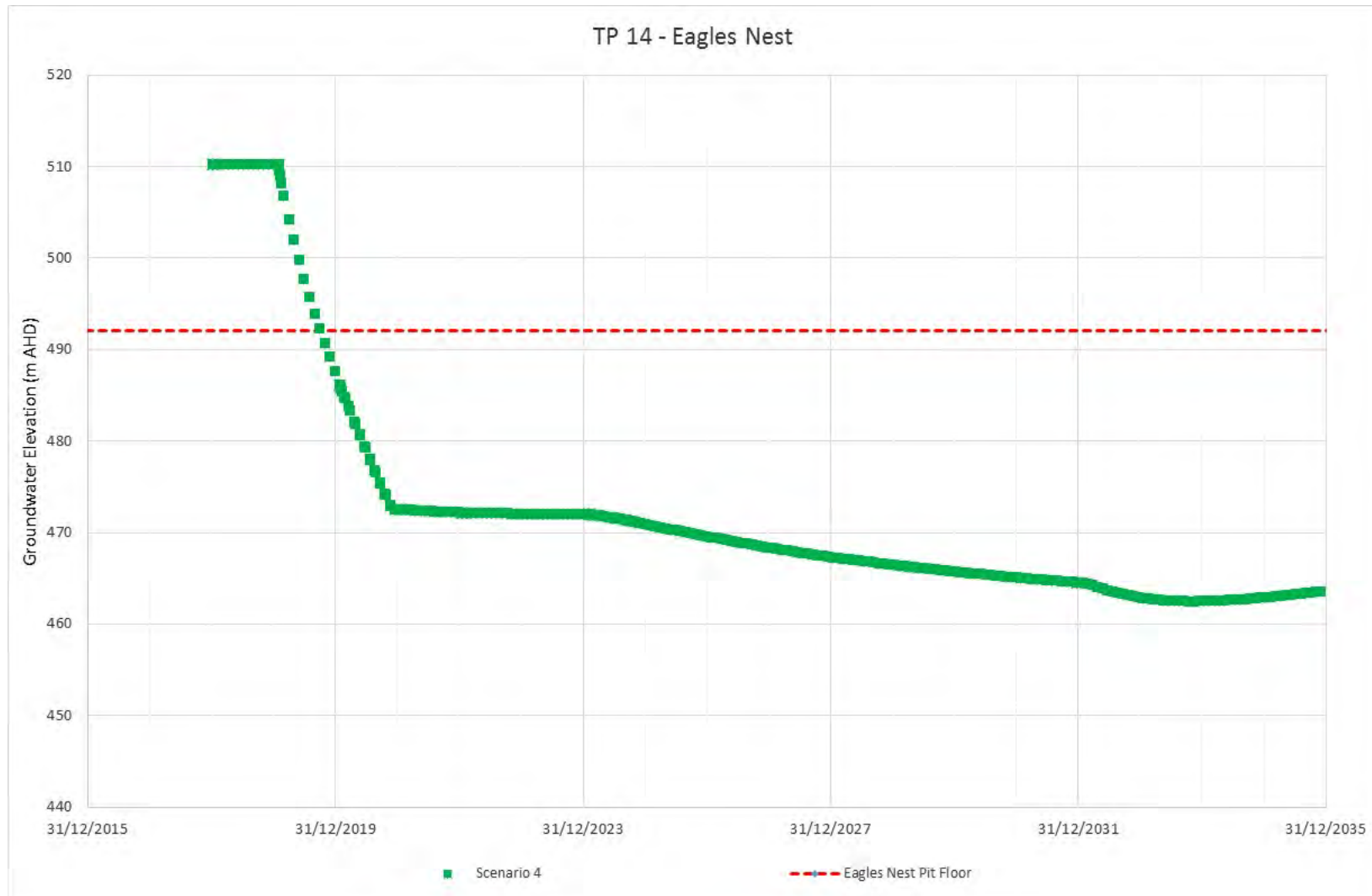
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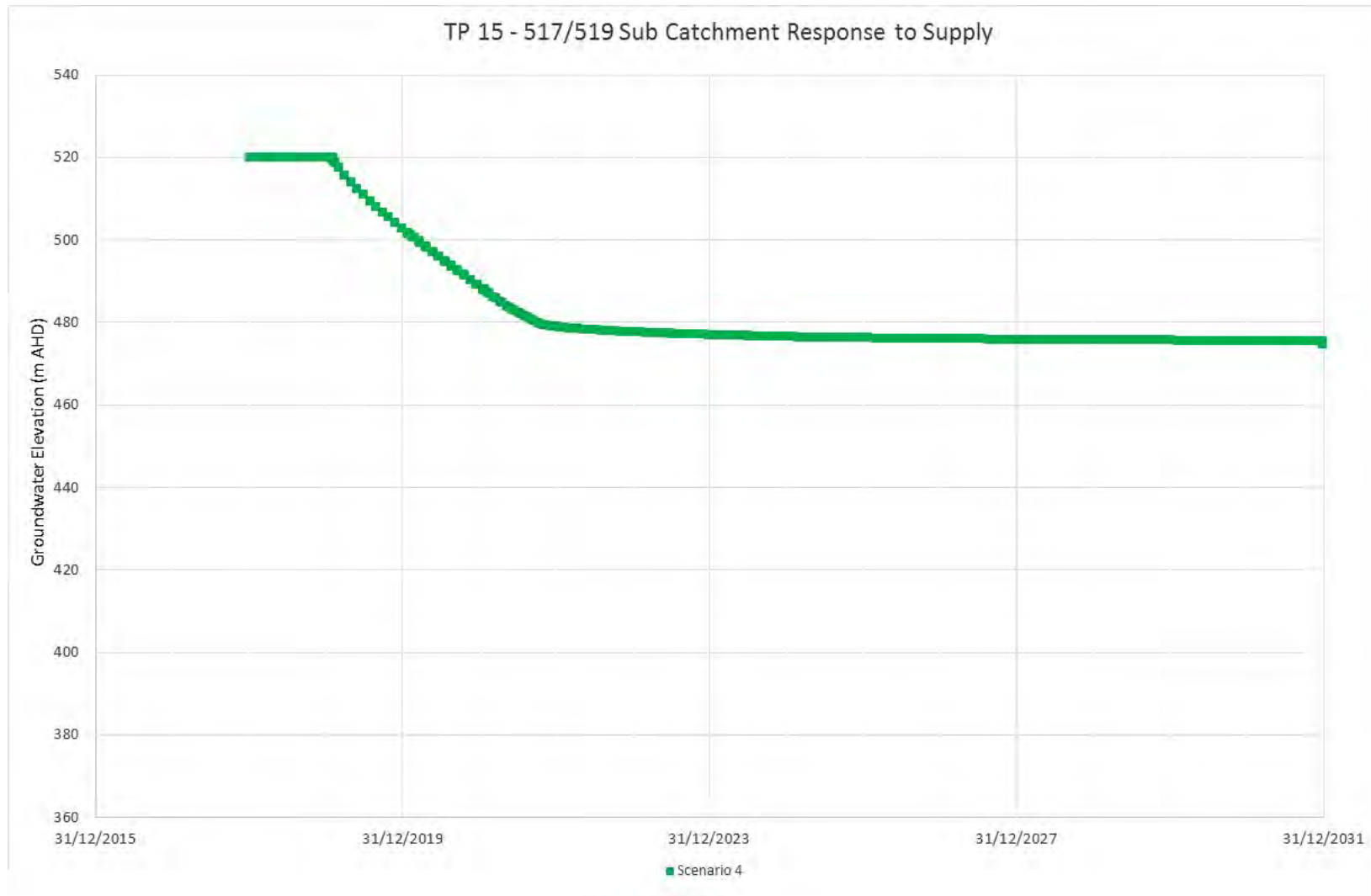
Groundwater Model Tracking Point Plots





APPENDIX A

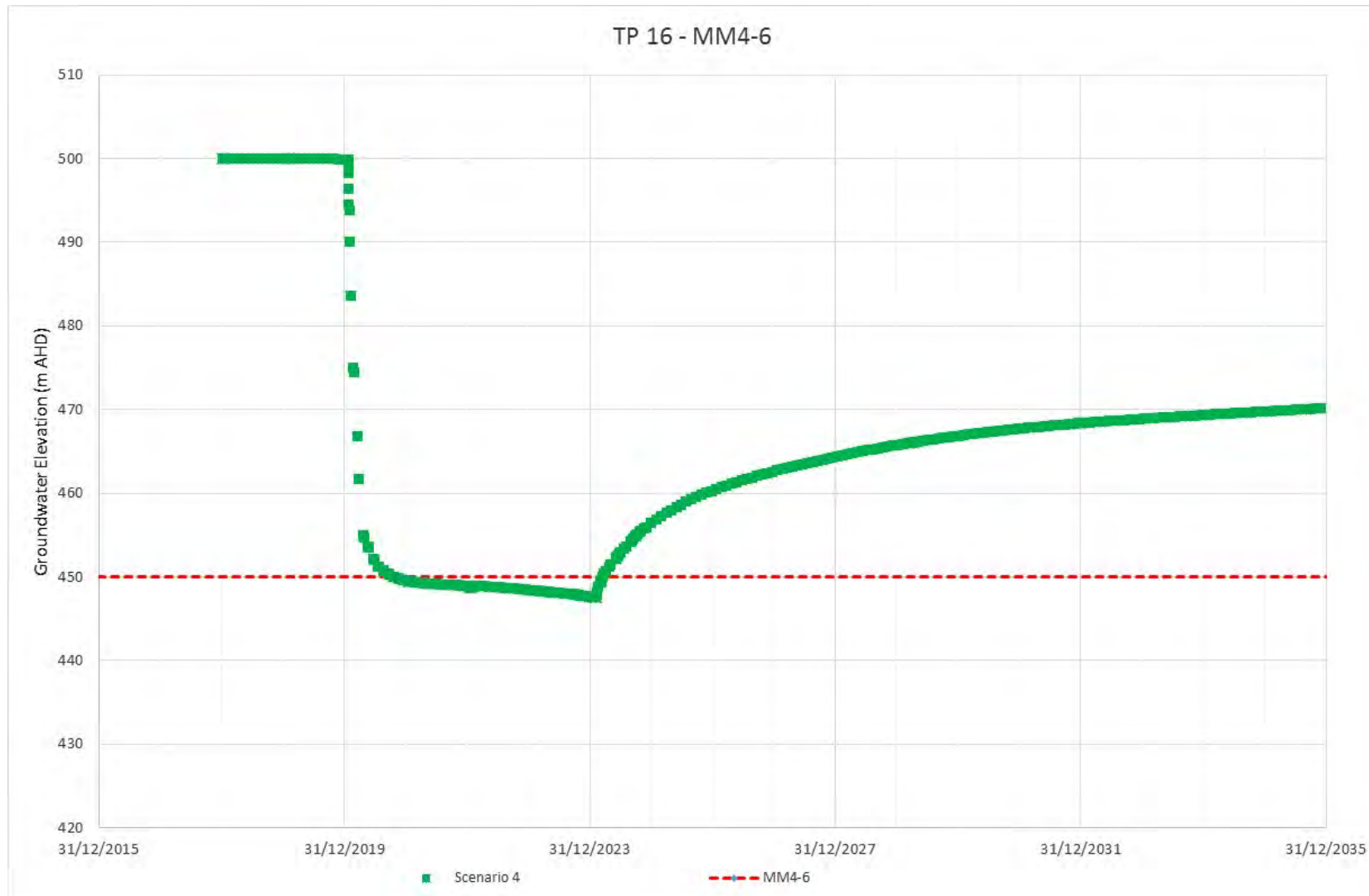
Groundwater Model Tracking Point Plots





APPENDIX A

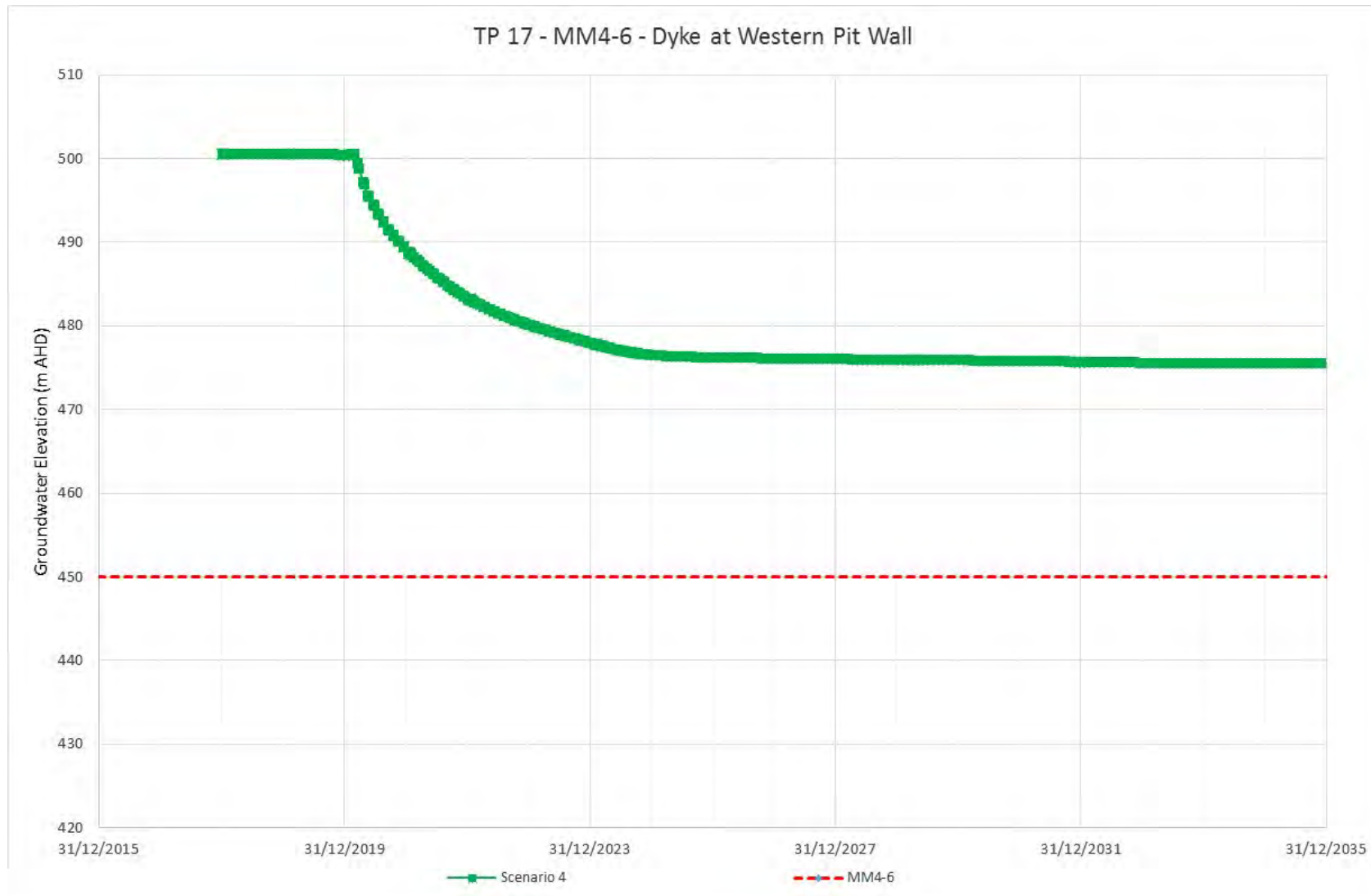
Groundwater Model Tracking Point Plots





APPENDIX A

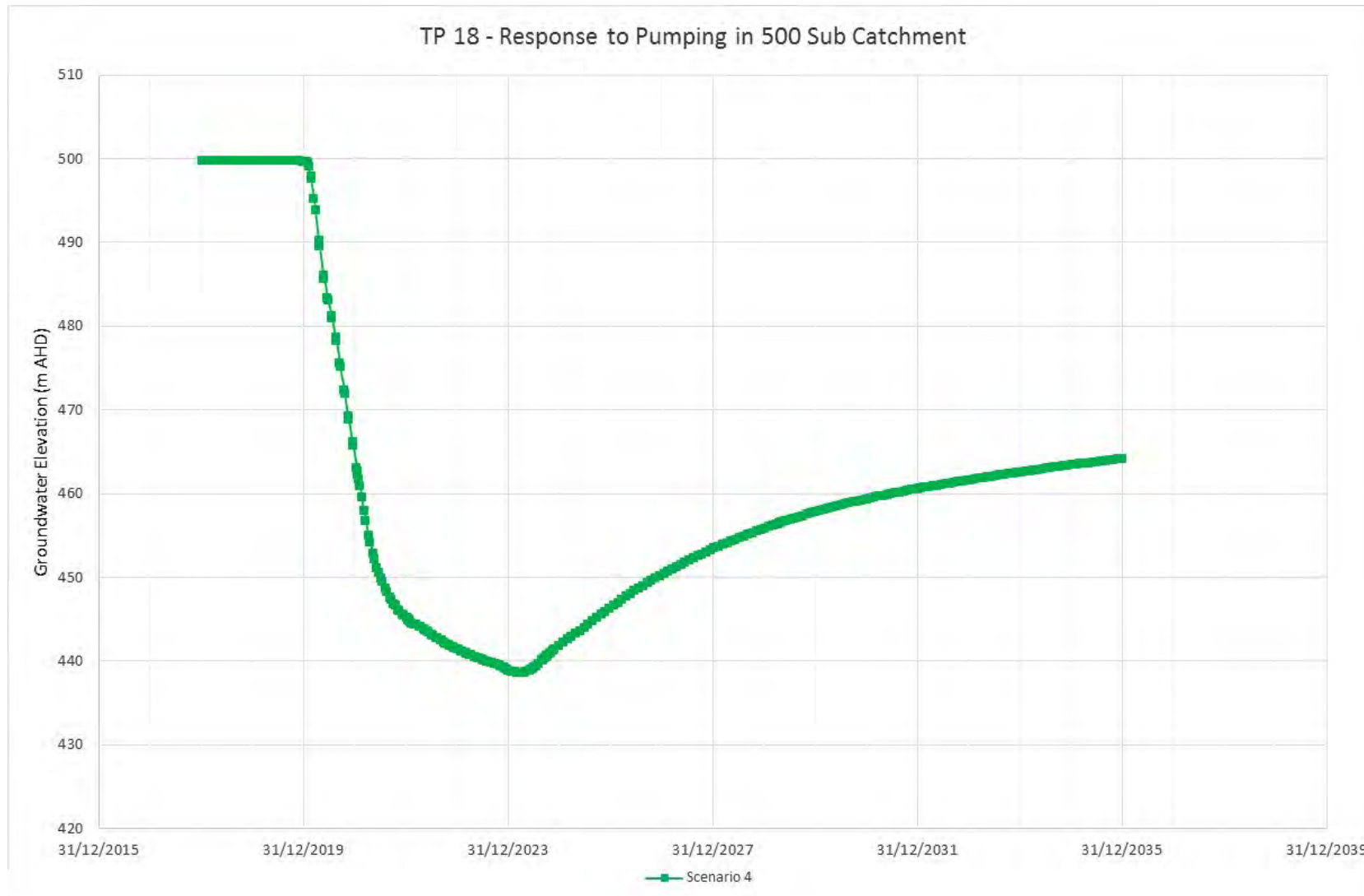
Groundwater Model Tracking Point Plots





APPENDIX A

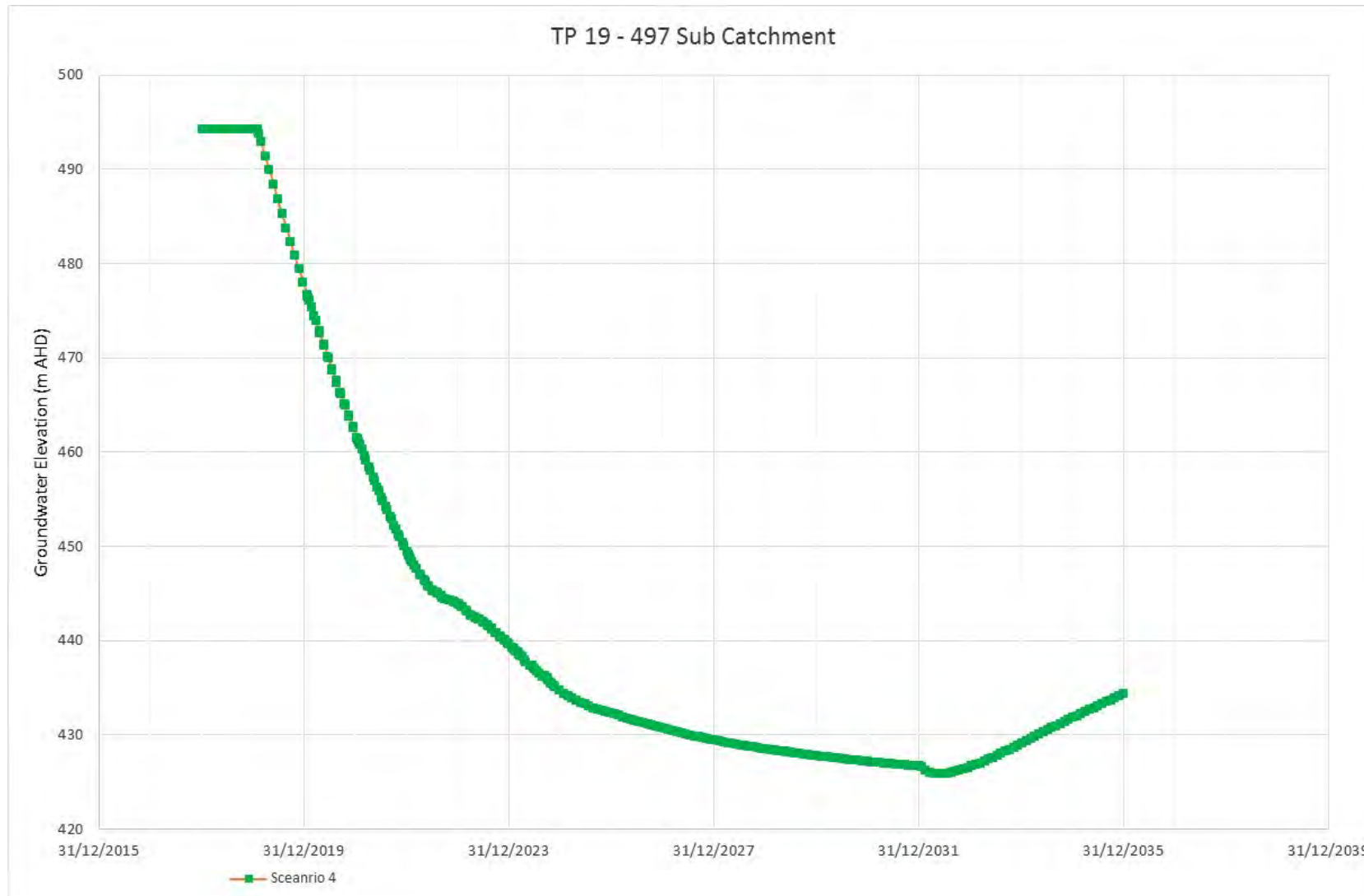
Groundwater Model Tracking Point Plots





APPENDIX A

Groundwater Model Tracking Point Plots





APPENDIX B

Mine Void Analytical Model Methodology



MINE VOID WATER BALANCE MODELS

Analytical mine void water balance models are commonly used to assess inflows, outflows and water levels and water quality within the voids. By their nature, these models represent a simplification of the natural system for estimating potential outcomes given a range of values for key hydrological variables. The models can be used to identify which variables are critical to each outcome, how each variable potentially impacts these outcomes and the plausible range of outcomes for assumed variables, given knowledge and understanding of the hydrological system. As such, analytical models are not accurate predictors of final mine void lake levels and water quality.

Models have been developed for the Eliwana mine voids. Importantly, the models use interpolated relationships between pit depth and total volume and total surface area in 1m metre increments supplied by FMG (based on their latest pit shells from the mine plan).

The models utilise daily time steps and rainfall and evaporation (daily) rates based on the SILO gridded rainfall and evaporation data from 1889 to present day for the midpoint location of the Eliwana project.

Each mine void water balance model incorporates the following inputs and outputs.

- Rainfall as direct recharge to mine void lake surface
- Rainfall run-off from mine void walls
- Head dependent groundwater inflow based on the sub catchment boundary head post dewatering and the water level in the mine void lake
- Evaporation from the mine void lake surface
- Surface water catchment inflows

The key parameters for determining the inputs and outputs comprise the following variables:

- R = Daily rainfall (mm/day)
- E = Daily evaporation (mm/day)
- H_b = Head at the sub catchment boundary (m RL)
- S = Mine void water level (m RL)
- B_{RL} = Minimum mine bench RL
- P_e = pan factor (dimensionless factor)
- R_e = effective radius from the midpoint of the pit to the groundwater sub catchment boundary (m)
- R_{pw} = pit wall rainfall cut-off value, the amount below which no pit wall run-off volume is included (mm)
- R_c = surface water catchment rainfall cut-off, the amount below which no surface water catchment is included (mm)
- C_r = rainfall run-off coefficient (dimensionless factor)
- SCA = Surface water Catchment Area (m^2)



APPENDIX B

Mine Void Analytical Model Methodology

- PCA = Pit wall Catchment Area (m^2)
- V_{TSA} = mine void lake surface area interpolated from S (m^2)
- V = mine void volume interpolated from S (m^3)
- k = horizontal hydraulic conductivity (m/day)

The process flow comprises the following series of operations for n steps:

- Convert S to V_n .
- If $S > B_{RL}$, then rainfall input = $R \times V_{TSA}$. If $S < B_{RL}$, rainfall input into pit void equals zero
- If $R > R_{pw}$, then pit wall run-off = $R \times PCA \times C_r$. If $R < R_{pw}$, pit wall run-off equals zero
- If $R > R_c$, then catchment runoff = $R \times SCA \times C_r$. If $R < R_c$, catchment runoff equals zero
- If $S > B_{RL}$, then evaporative loss = $E \times P_e \times V_{TSA}$. If $S < B_{RL}$, evaporation equals zero
- If $S > B_{RL}$, then groundwater flow = $\pi \times k \times (H_b^2 - S^2) / 2.3 \log_{10}(R_e)$. If $H_b > S$ groundwater added, if $H_b < S$ groundwater subtracted.
- Sum change in volume to give V_{n+1} . Convert V_{n+1} to S_{n+1}

Figure A1 provides a graphical representation of the water inflow and outflow components represented in the models. A range of input values were used to simulate a range of possible outcomes for each pit void, a summary of these for each pit is provided in Tables 1 to 5 below.

Note: The ranges in groundwater heads used to simulate the flow of groundwater towards/away from the pit void were based on the higher values derived from Scenario 6 FEFLOW modelling and the lower values calculated using analytical storage depletion calculations for each groundwater sub-catchment (based on the dewatered volume, catchment area and specific yield of 1 %).

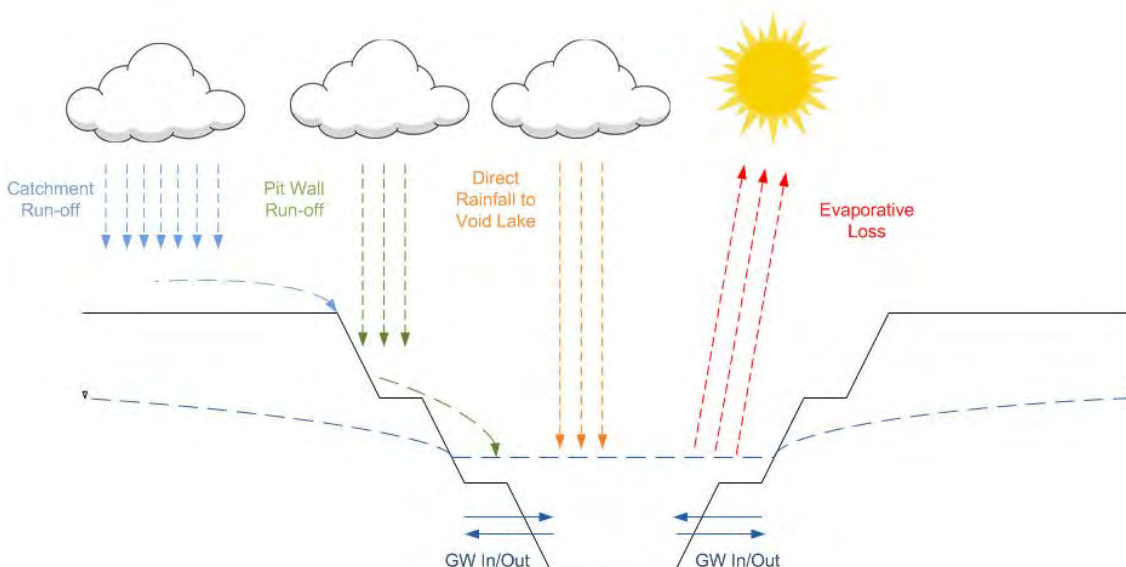


Figure A1: Pit Lake Model Input/output Summary



APPENDIX B

Mine Void Analytical Model Methodology

Table 1: Summary of Westend Model Parameters

Parameter/Alias	Mean K High GW Head High EV	Mean K High GW Head Low EV	Mean K Low GW Head Low EV	Low K Low GW Head High EV	Low K High GW Head High EV	Low K Low GW Head Low EV Low Run-off	V Low K High GW Head Low EV	V Low K Low GW Head Low EV
Hydraulic conductivity (m/d)	1	1	1	0.1	0.1	0.1	0.01	0.01
Post mining head at effective radius (m AHD)	470	470	440	440	470	440	470	440
Effective radius from pit to post mining head (m)	2800	2800	2800	2800	2800	2800	2800	2800
Pan evaporation factor	0.6	0.4	0.4	0.6	0.6	0.4	0.4	0.4
Rainfall cut-off (mm)	5	5	5	5	5	5	5	5
Catchment run-off value (mm)	0	0	0	0	0	0	0	0
Run-off co-efficient of pit walls	20%	20%	20%	20%	20%	50%	20%	20%



APPENDIX B

Mine Void Analytical Model Methodology

Table 2: Summary of Talisman Model Parameters

Parameter/Alias	Mean K High Head GW	Mean K Med. Head GW	Mean K Low Head GW	Low K High Head Low Run-off GW	Low K Med. Head GW	Low K Low Head GW	Low K Low Head High Run-off GW	V Low K High Head GW	V Low K Med. Head GW	V Low K Low Head GW
Hydraulic conductivity (m/d)	5	5	5	1	1	1	1	0.1	0.1	0.1
Post mining head at effective radius (m AHD)	465	430	420	465	430	420	420	465	430	420
Effective radius from pit to post mining head (m)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Pan evaporation factor	0.6	0.6	0.4	0.6	0.6	0.6	0.6	0.4	0.6	0.6
Rainfall cut-off (mm)	5	5	5	0	5	5	5	5	5	5
Catchment run-off (mm)	30	20	30	30	20	20	30	30	30	30
Run-off co-efficient of pit walls	30%	20%	20%	30%	20%	20%	20%	20%	20%	20%



APPENDIX B

Mine Void Analytical Model Methodology

Table 3: Summary of Broadway West Model Parameters

Parameter/Alias	Mean K High Head GW	Mean K Low Head GW	Mean K Low GW Head Low Run-off	Low K High Head GW	Low K Low Head GW	Low K Low Head Low Run-off Low EV	V Low K High Head Low EV	V Low K Med. Head Low EV	V Low K Low Head Low EV
Hydraulic conductivity (m/d)	5	5	5	1	1	1	0.1	0.1	0.1
Post mining head at effective radius (m AHD)	380	360	360	380	360	360	380	370	360
Effective radius from pit to post mining head (m)	6800	6800	6800	6800	6800	6800	6800	6800	6800
Pan evaporation factor	0.6	0.6	0.6	0.6	0.6	0.4	0.4	0.4	0.4
Rainfall cut-off (mm)	5	5	5	5	5	5	0	5	5
Catchment run-off value (mm)	30	30	20	30	30	30	30	30	30
Run-off co-efficient of pit walls	20%	20%	20%	20%	20%	10%	15%	20%	20%



APPENDIX B

Mine Void Analytical Model Methodology

Table 4: Summary of MM4-6 Model Parameters

Parameter/Alias	Mean K High GW Head	Mean K High GW Head Low Run-off	Mean K Med. GW Head	Mean K Med, GW Head High Run-off	Mean K Med GW Head Low Run-off	Low K High GW Head	Low K Med. GW Head
Hydraulic conductivity (m/d)	5	5	5	5	5	1	1
Post mining head at effective radius (m AHD)	475	475	460	460	460	475	460
Effective radius from pit to post mining head (m)	2600	2600	2600	2600	2600	2600	2600
Pan evaporation factor	0.6	0.6	0.6	0.5	0.5	0.5	0.5
Rainfall cut-off (mm)	0	5	5	5	5	5	5
Catchment run-off value (mm)	30	20	30	30	30	30	30
Run-off co-efficient of pit walls	15%	10%	15	20%	15%	15%	20%



APPENDIX B

Mine Void Analytical Model Methodology

Table 4 Cont. Summary of MM4-6 Model Parameters

Parameter/Alias	Low K Low GW Head	Low K Low GW Head Low EV	V Low K Med. GW Head	V. Low K Low GW Head Low Run-off	V. Low K Low GW Head V. Low Run-off	V Low K High Run-off	V. Low K Low GW Head Low EV
Hydraulic conductivity (m/d)	1	1	0.1	0.1	0.1	0.1	0.1
Post mining head at effective radius (m AHD)	450	450	460	450	450	450	450
Effective radius from pit to post mining head (m)	2600	2600	2600	2600	2600	2600	2600
Pan evaporation factor	0.5	0.4	0.6	0.6	0.6	0.6	0.4
Rainfall cut-off (mm)	5	5	5	5	0	0	0
Catchment run-off value (mm)	30	30	30	30	20	30	30
Run-off co-efficient of pit walls	20%	20%	15%	15%	10%	10%	10%



APPENDIX B

Mine Void Analytical Model Methodology

Table 5: Summary of Westside Model Parameters

Parameter/Alias	Mean K Low GW Head High EV	Mean K Low GW Head Low EV	Mean K Low GW Head V Low EV	Mean K High GW Head	Low K Low GW Head	V Low K Low GW Head
Hydraulic conductivity (m/d)	1	1	1	1	0.1	0.01
Post mining head at effective radius (m AHD)	470	470	470	480	470	470
Effective radius from pit to post mining head (m)	8500	8500	8500	8500	8500	8500
Pan evaporation factor	0.6	0.5	0.4	0.5	0.5	0.5
Rainfall cut-off (mm)	2	5	5	5	5	5
Catchment run-off value (mm)	20	20	0	0	0	0
Run-off co-efficient of pit walls	20%	20%	20%	20%	20%	20%



MINE VOID WATER QUALITY (CHLORIDE BALANCE) MODELS

Chloride balance calculations were carried out to assess likely long-term water quality changes and are based on an extension of the mine void water balance models. Each water inflow/outflow was assigned a chloride concentration to calculate the change in chloride load for every step (n) and the according chloride concentration was then calculated based on the final volume of water in the mine void as calculated in the water balance models.

The following chloride concentrations were adopted:

- Groundwater – Envirosearch Data as provided by Fortescue on an individual groundwater sub catchment basis. Values range between 100 and 1000 mg/L
- Assumed chloride concentration in Rainfall – 0.5 mg/L based on Hedley et al., (2009)
- Assumed chloride concentration in Pit Wall Runoff – 250 mg/L assuming some dissolution of salts residing in the pit walls (unsupported)
- Assumed chloride concentration in Catchment Runoff – 10 mg/L. Given the magnitude of surface water flow this is expected to be at the lower end of that provided by Fortescue for the Ashburton catchment.
- Assumed chloride concentration in Evaporative loss – 0 mg/L. Evaporation of mine void water will not remove salts from the mine void water body.

For each step in the mine void water balance models, the above chloride concentrations were applied to the volume calculated to flow in/out of the void and the final chloride mass at each step (n) was used to calculate a concentration based on the final mine void water volume.

A sensitivity test was carried out for some of the chloride concentrations applied in the chloride balance models as detailed below:

- Westend:
 - Groundwater 170 mg/L up to 500 mg/L
 - Pit Wall Run-off 10 up to 500 mg/L
- Talisman:
 - Groundwater 100 mg/L up to 1000 mg/L
 - Pit Wall Run-off 250 mg/L up to 2500 mg/L
 - Catchment Run-off 10 mg/L up to 1000 mg/L
- Broadway West
 - Pit Wall Run-off 250 mg/L up to 2500 mg/L
 - Catchment Run-off 10 mg/L up to 1000 mg/L

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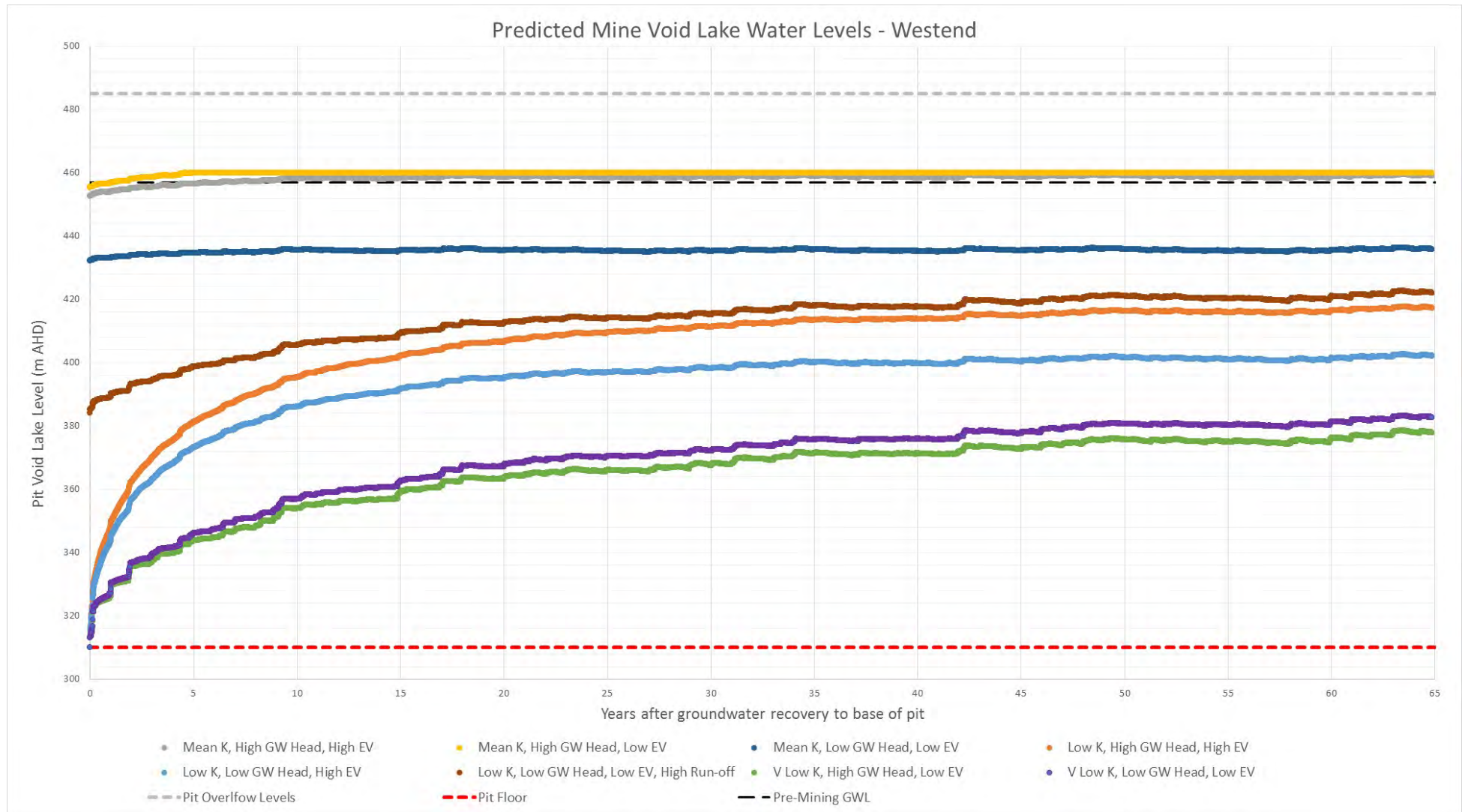
APPENDIX C

Mine Void Lake Model Results



APPENDIX C

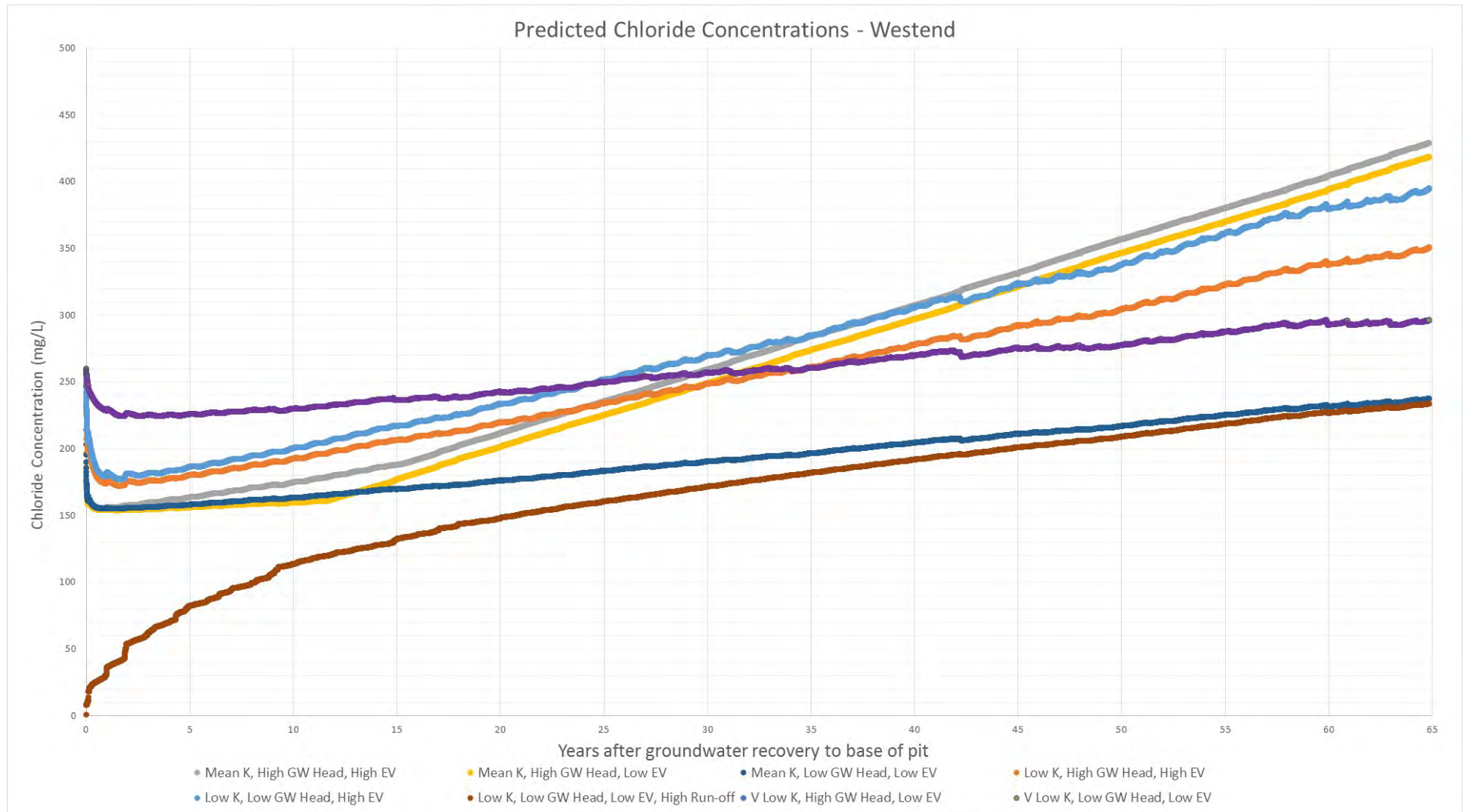
Mine Void Water Balance Models





APPENDIX C

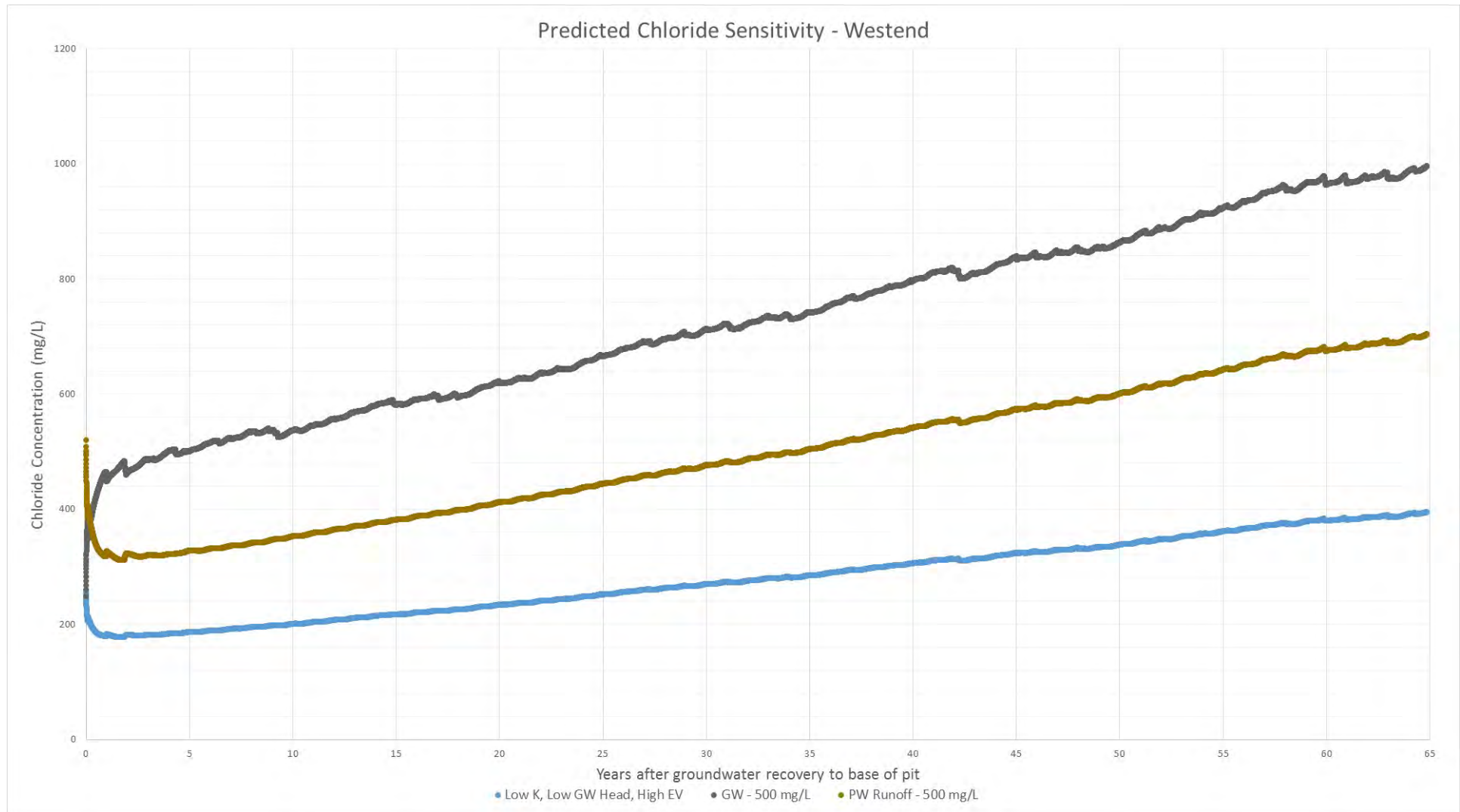
Mine Void Water Balance Models





APPENDIX C

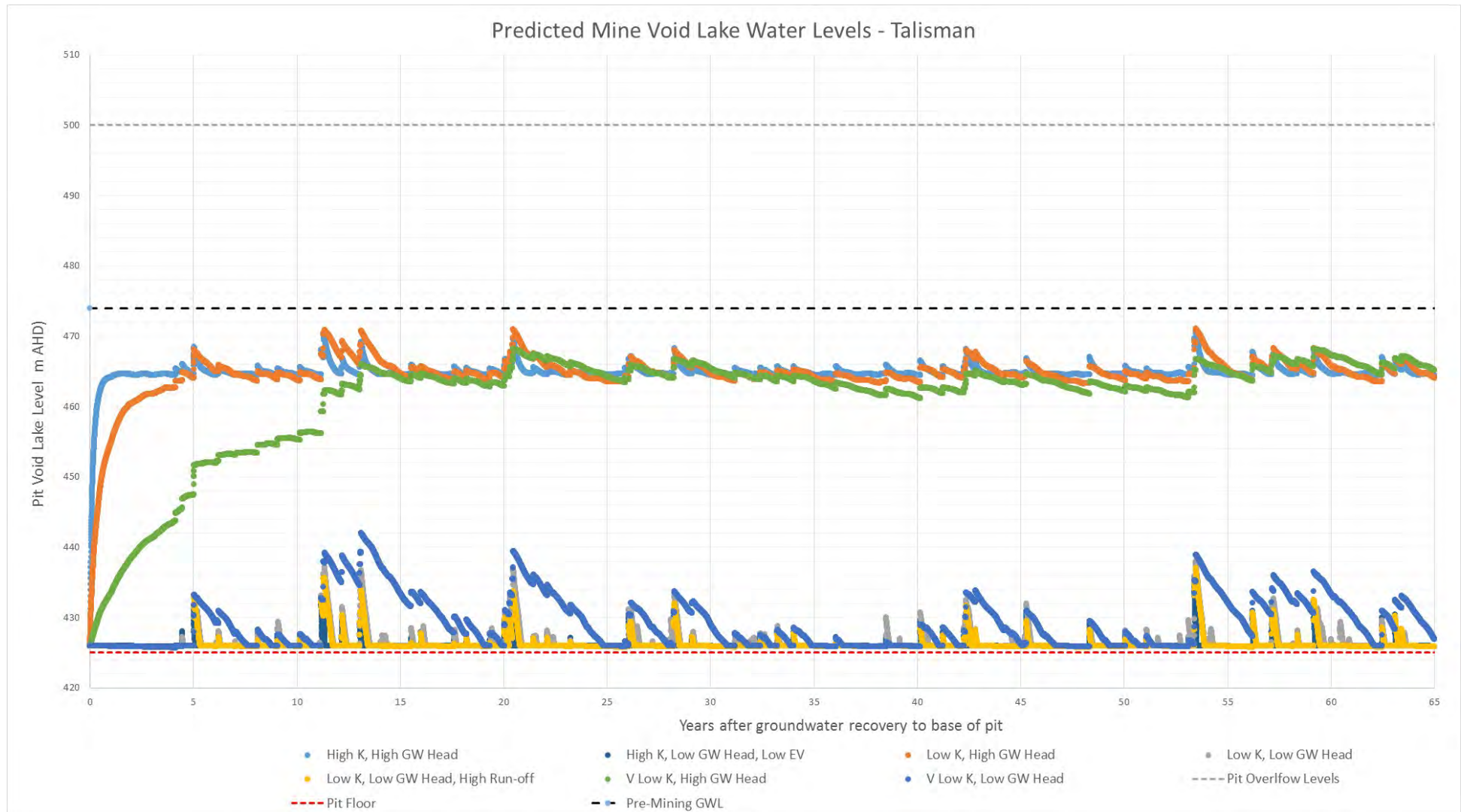
Mine Void Water Balance Models





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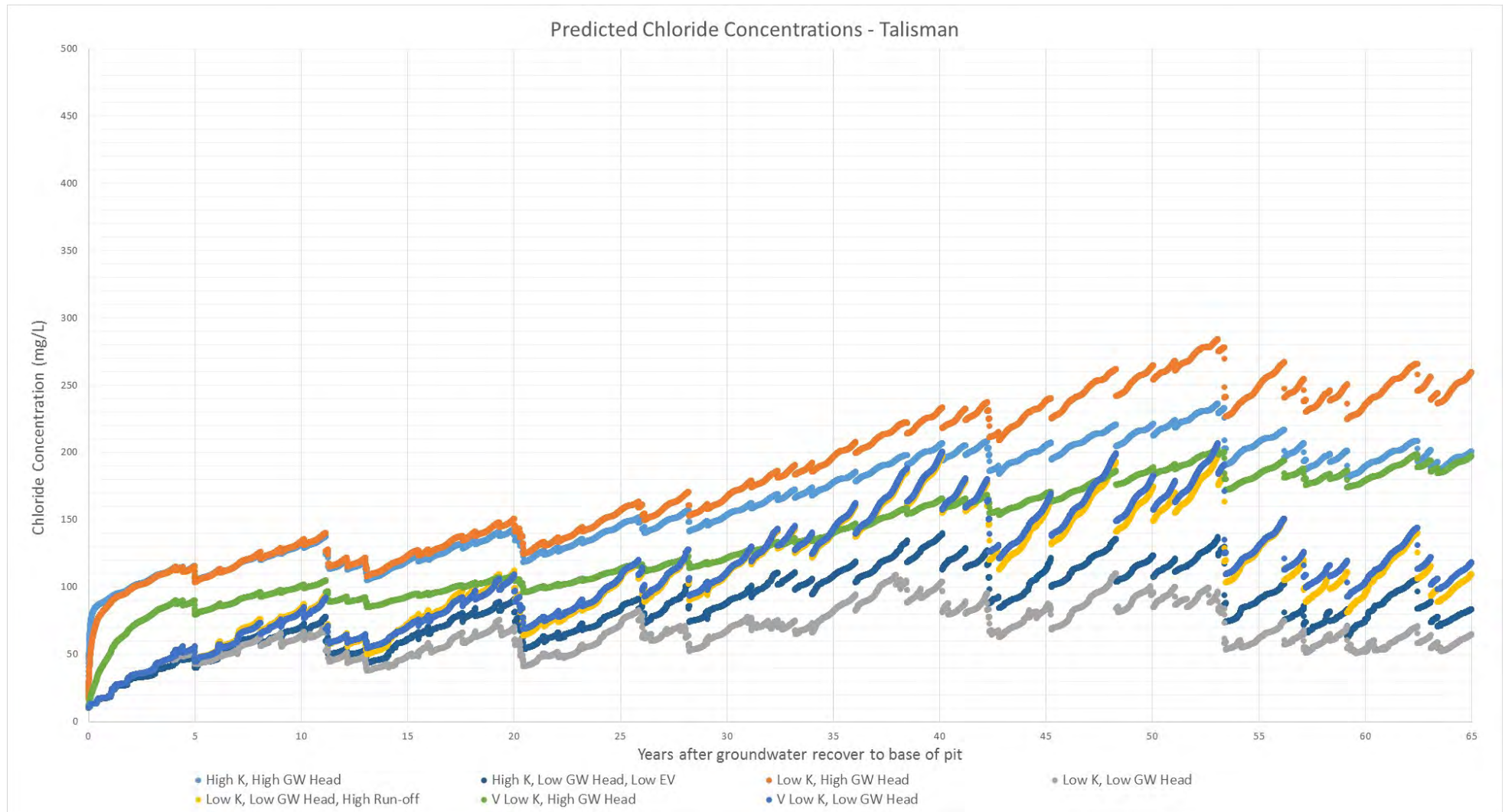
Mine Void Water Balance Models





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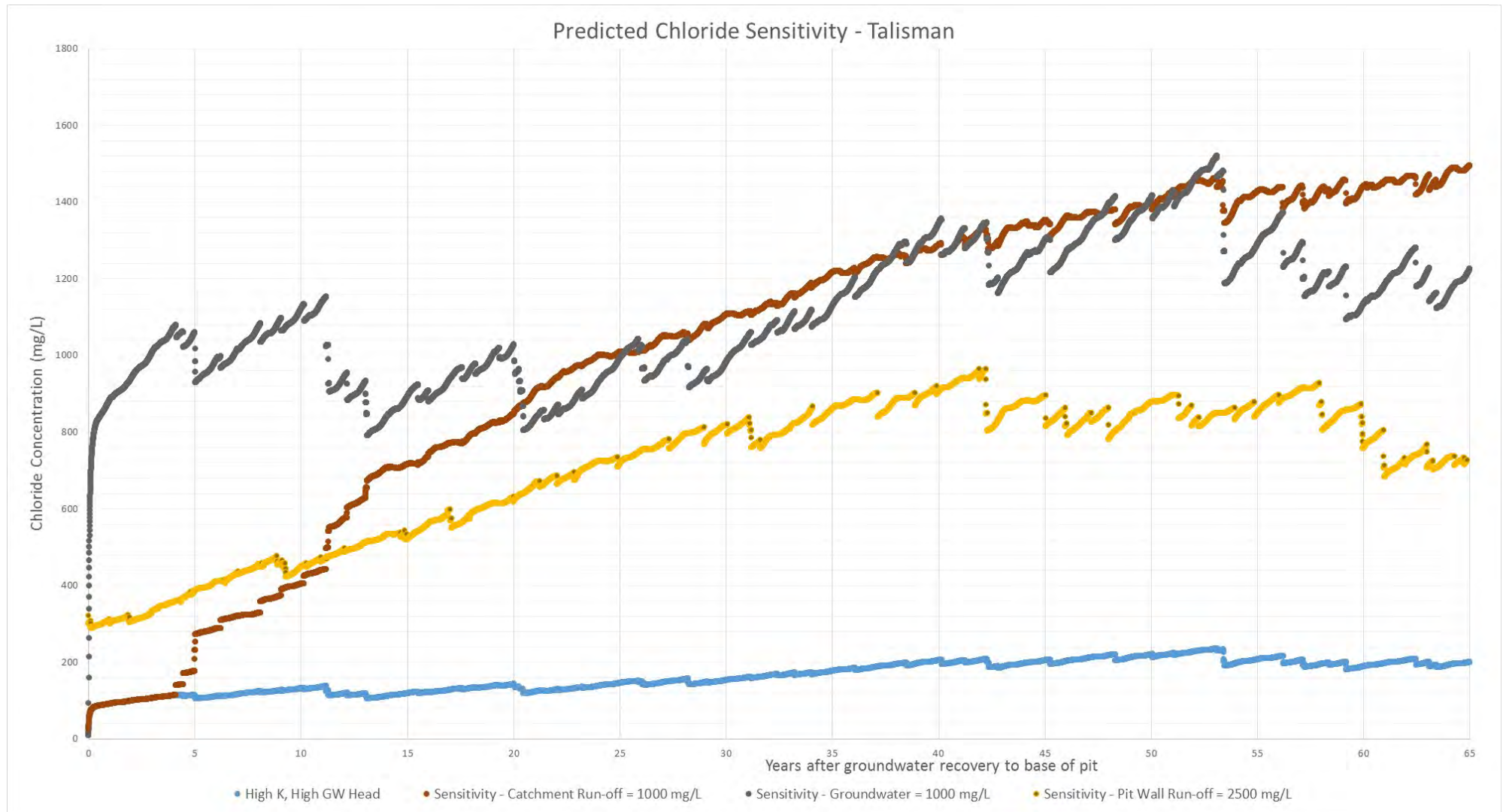
Mine Void Water Balance Models





APPENDIX C

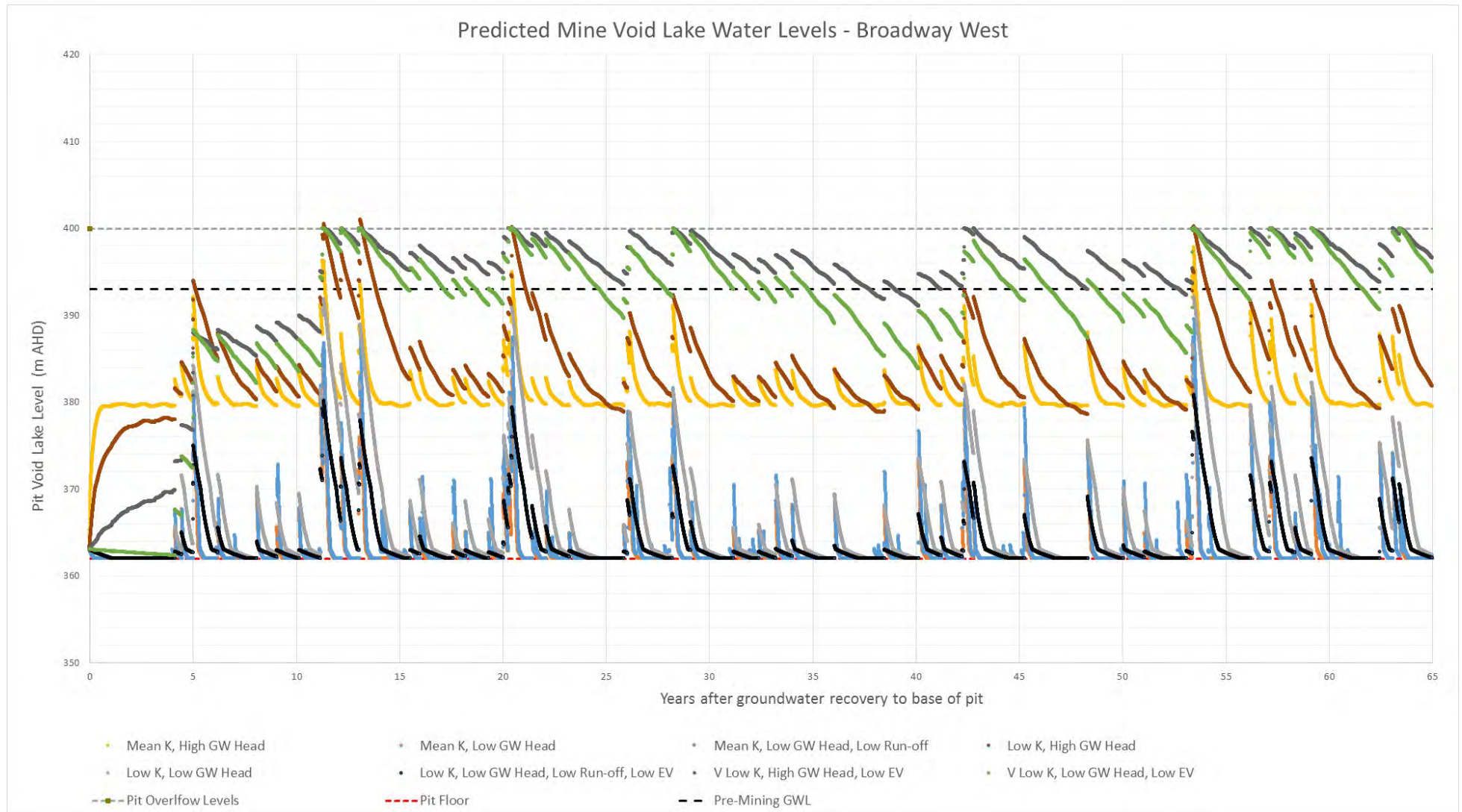
Mine Void Water Balance Models





APPENDIX C

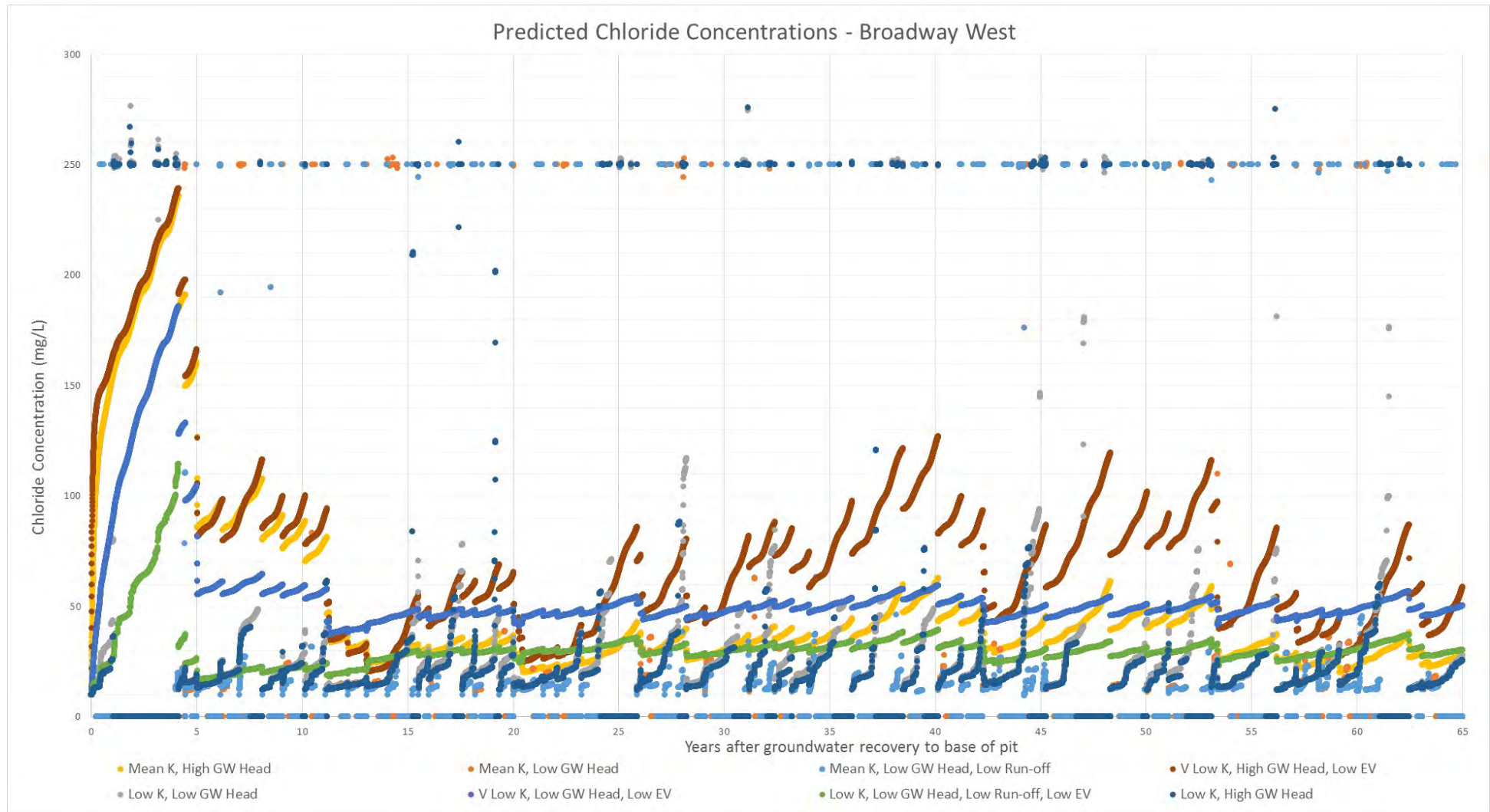
Mine Void Water Balance Models





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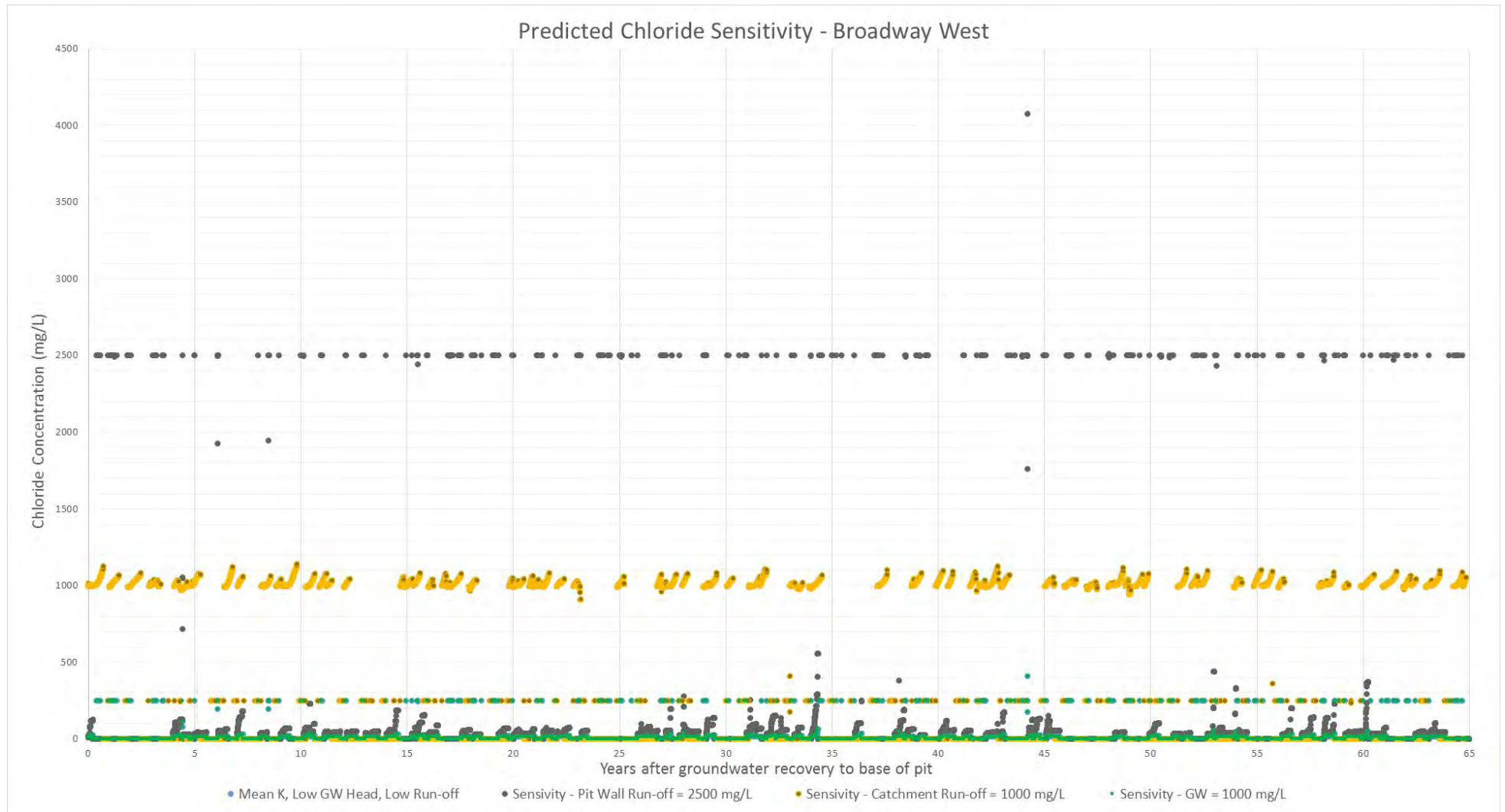
Mine Void Water Balance Models





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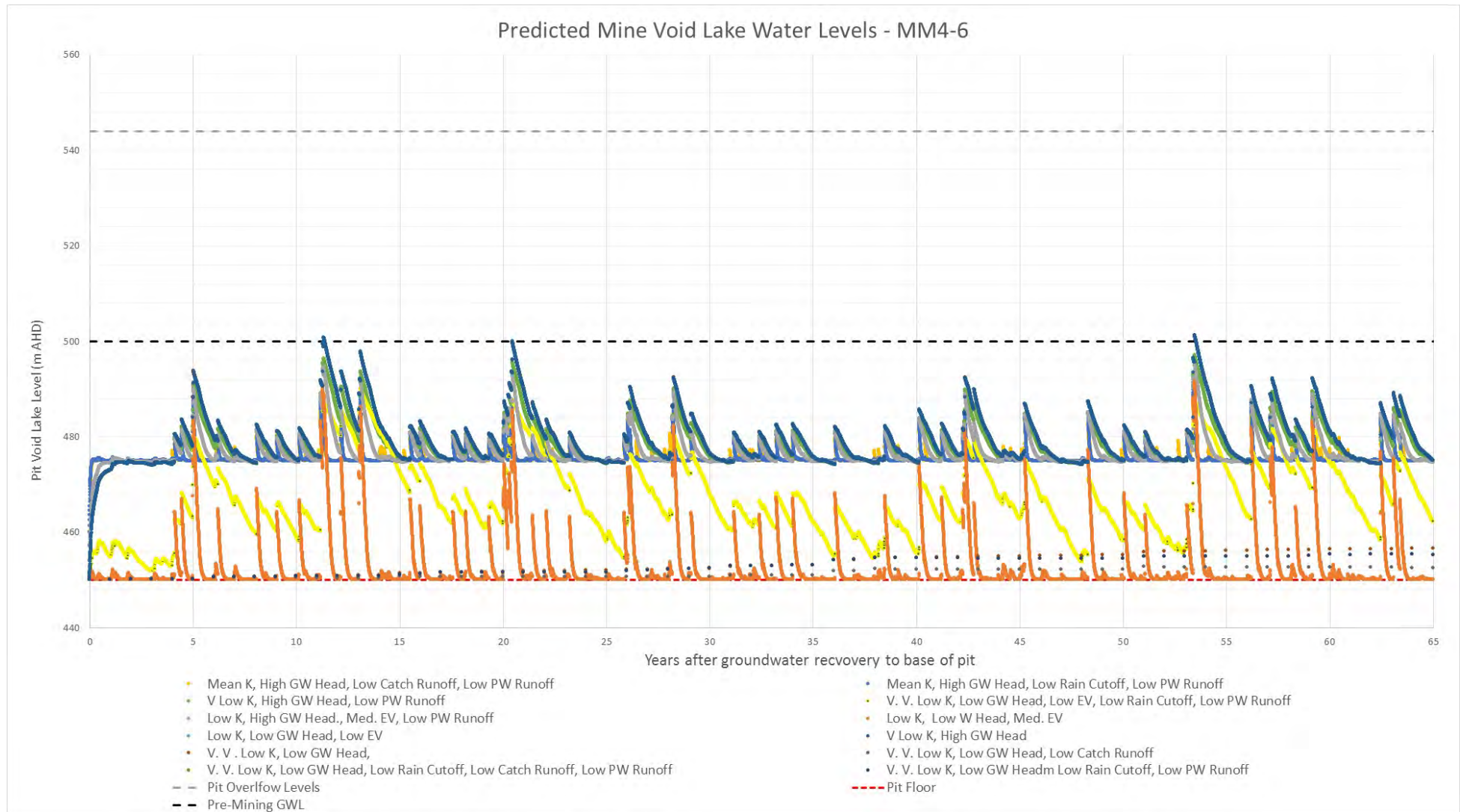
Mine Void Water Balance Models





APPENDIX C

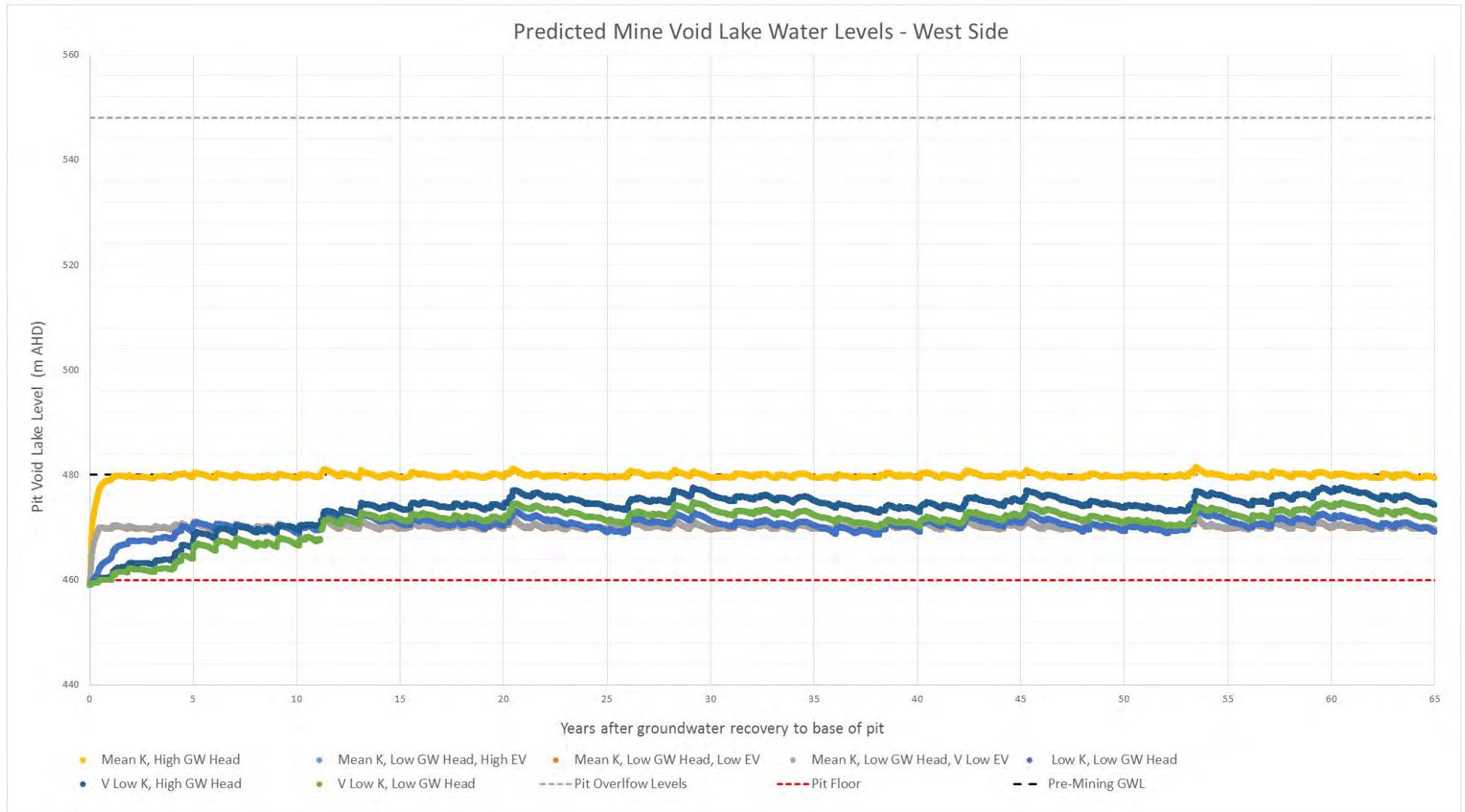
Mine Void Water Balance Models





APPENDIX C

Mine Void Water Balance Models





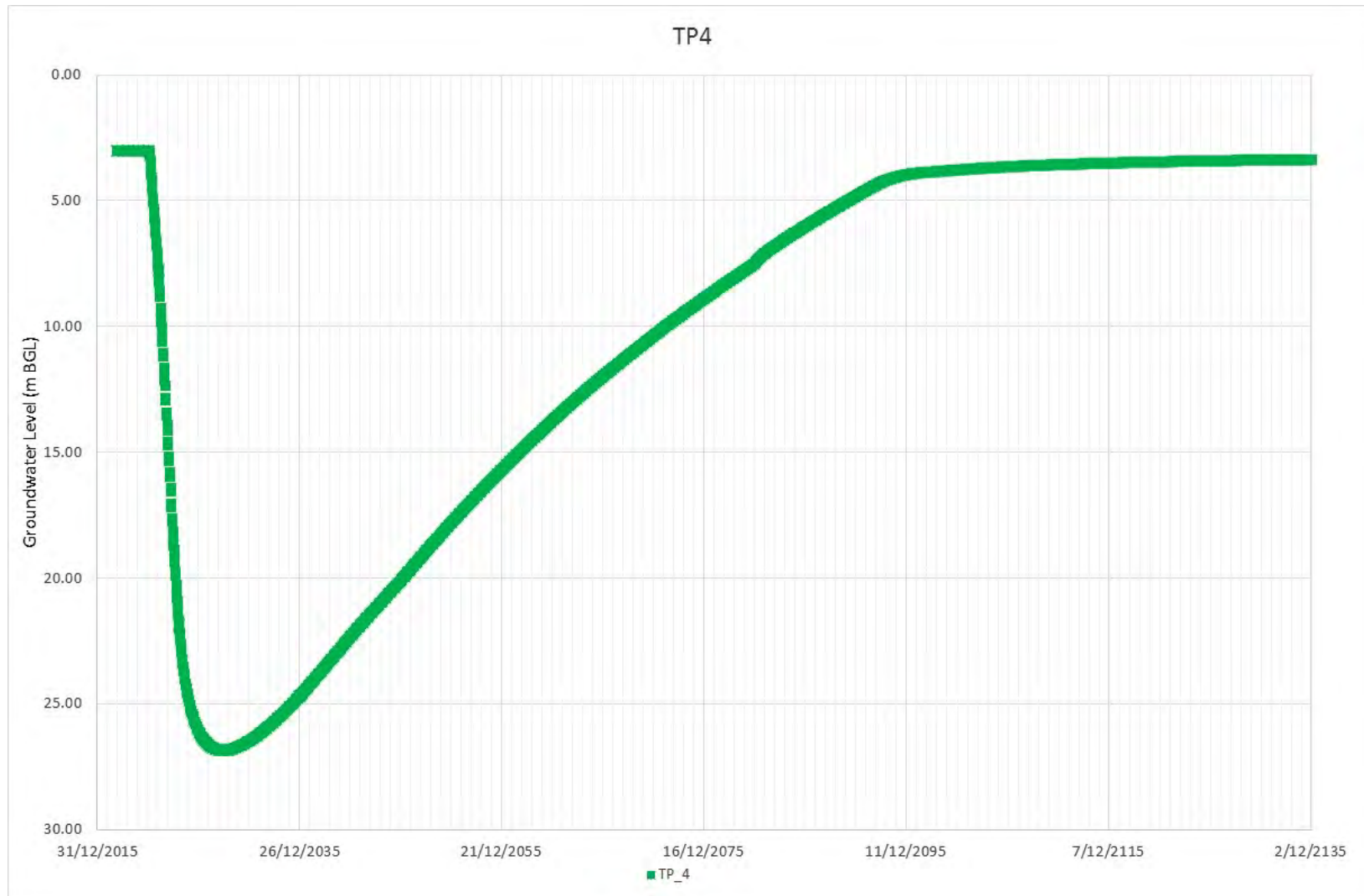
APPENDIX D

Depth to Groundwater at GDE Tracking Points



APPENDIX D

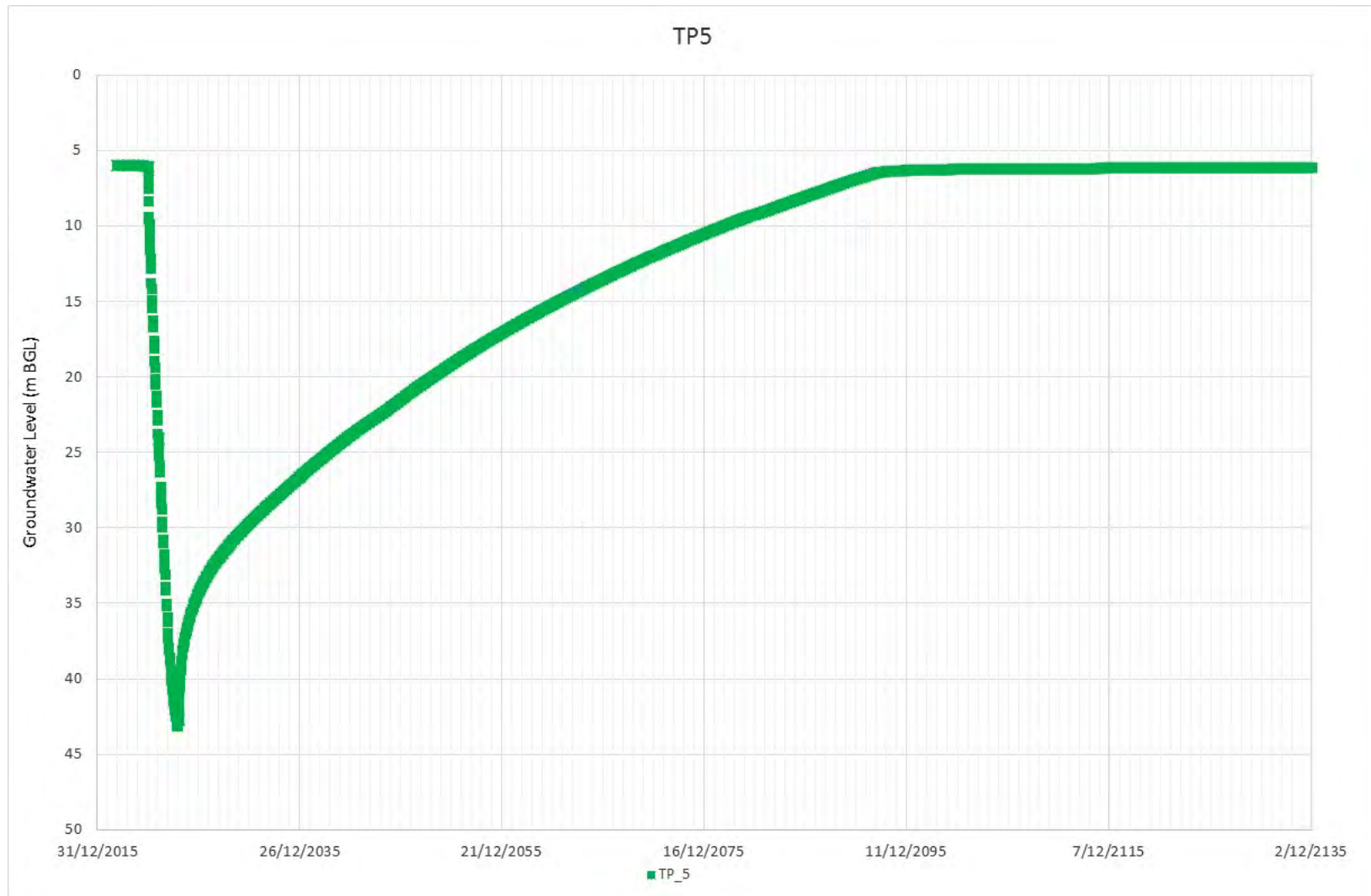
GDE Tracking Points





APPENDIX D

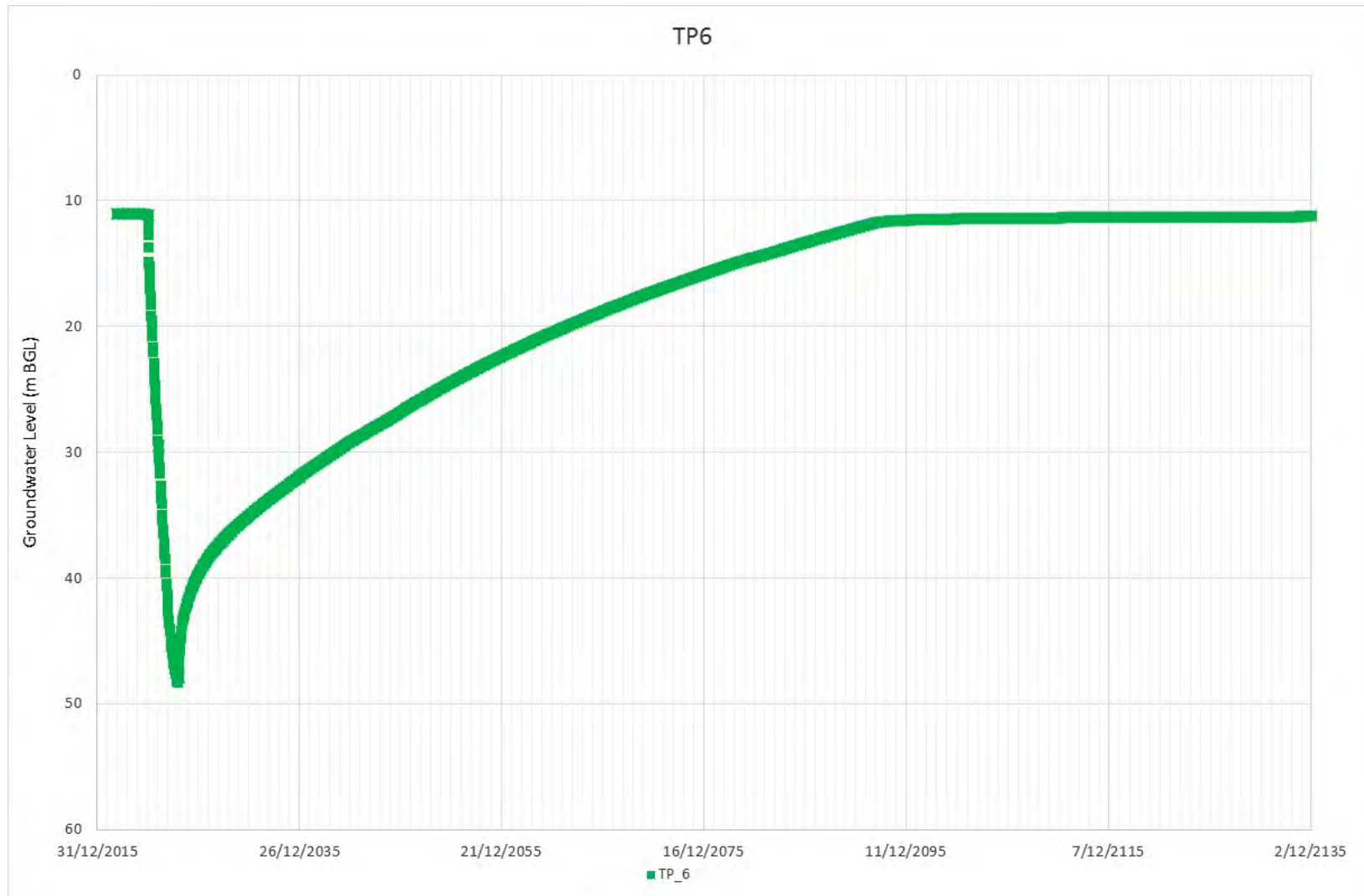
GDE Tracking Points





APPENDIX D

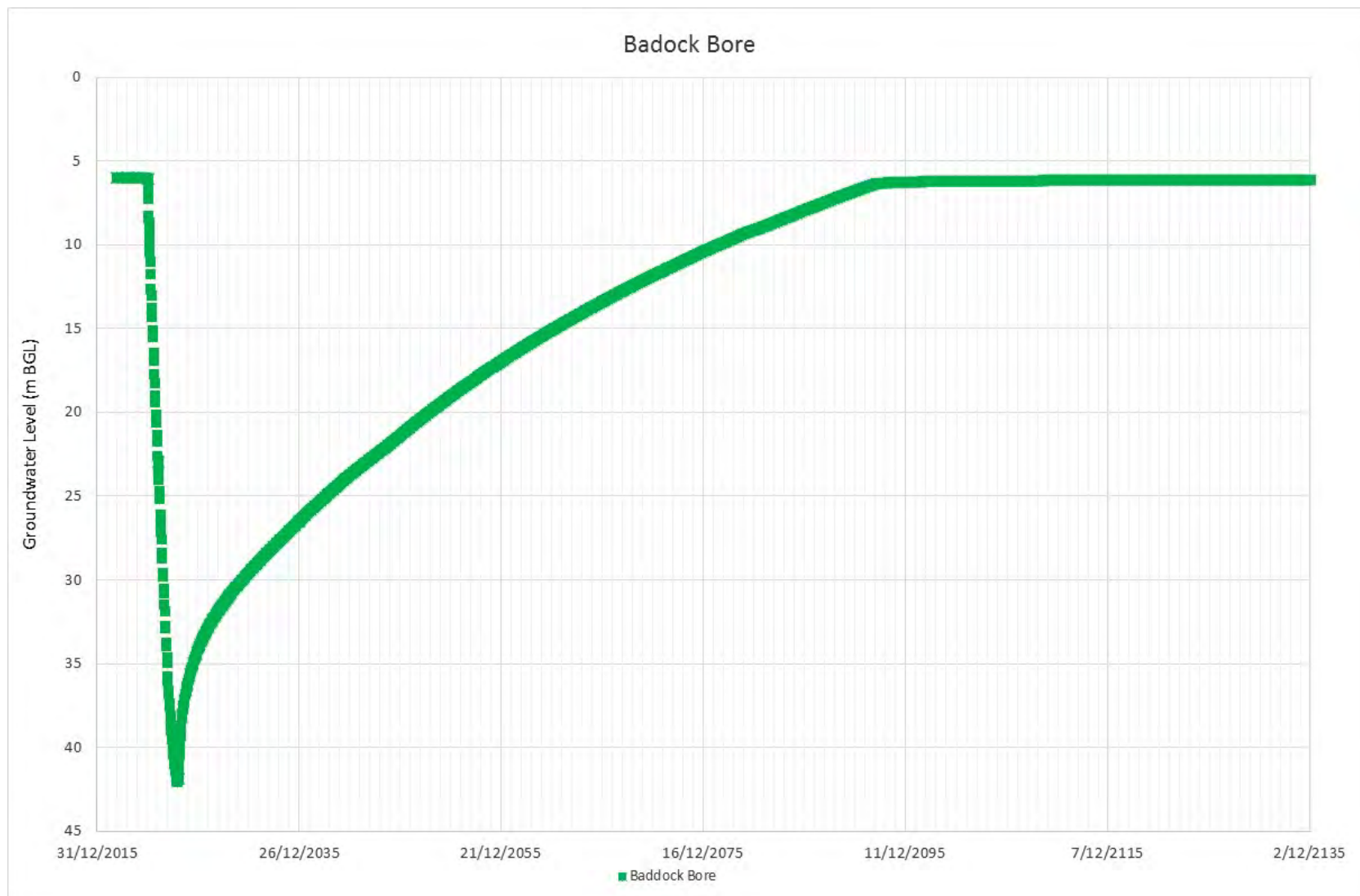
GDE Tracking Points





APPENDIX D

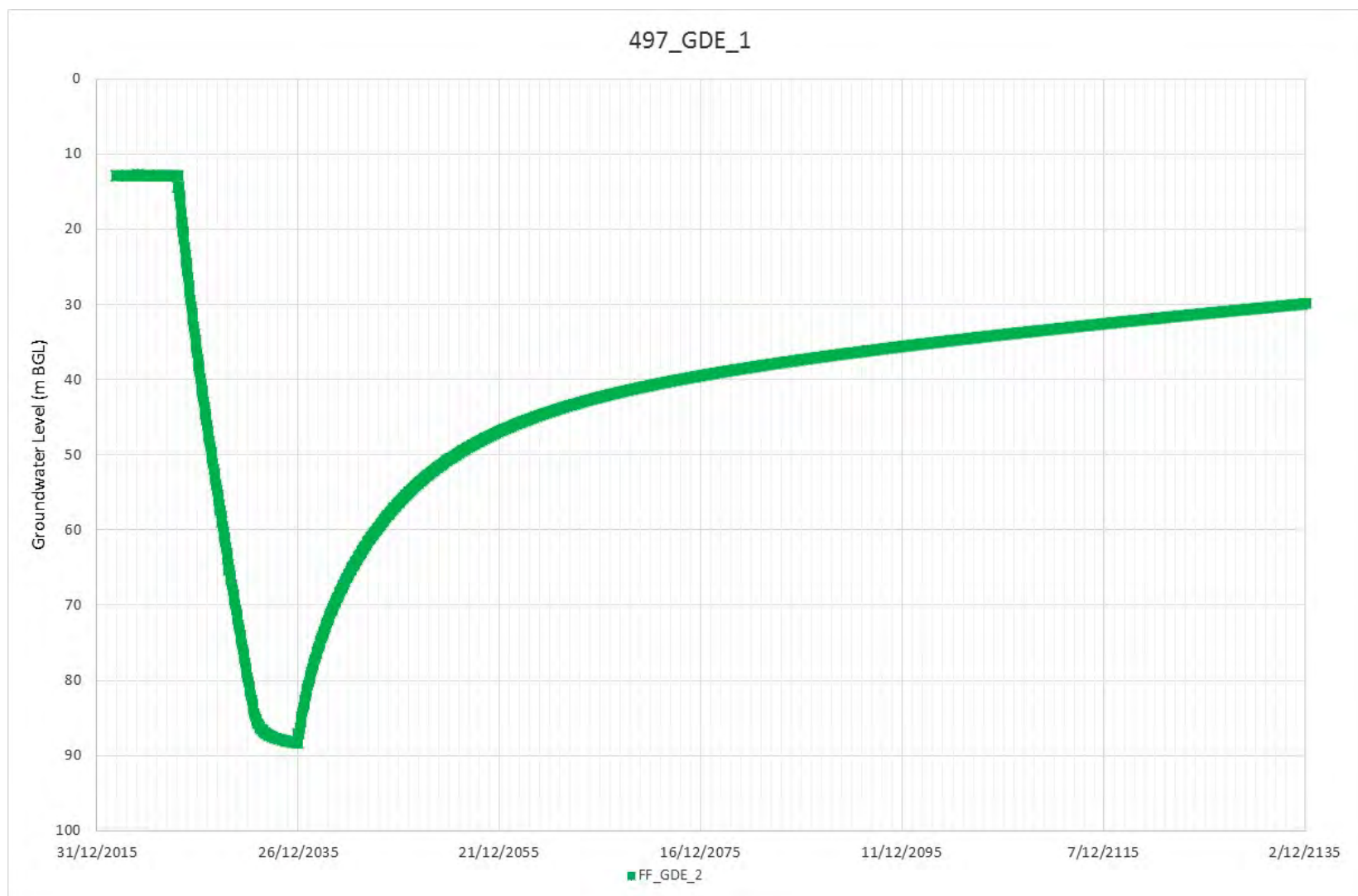
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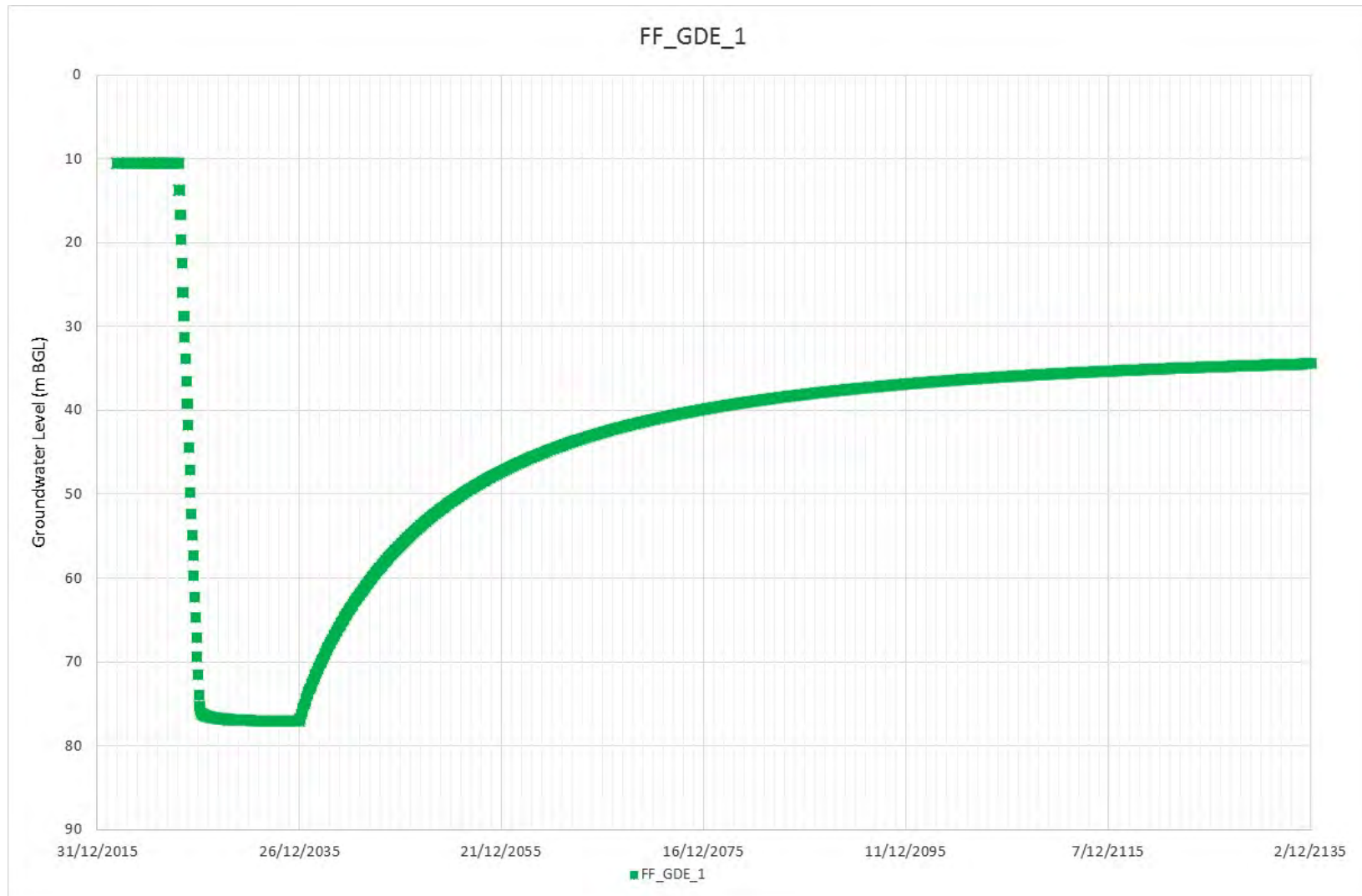
GDE Tracking Points





APPENDIX D

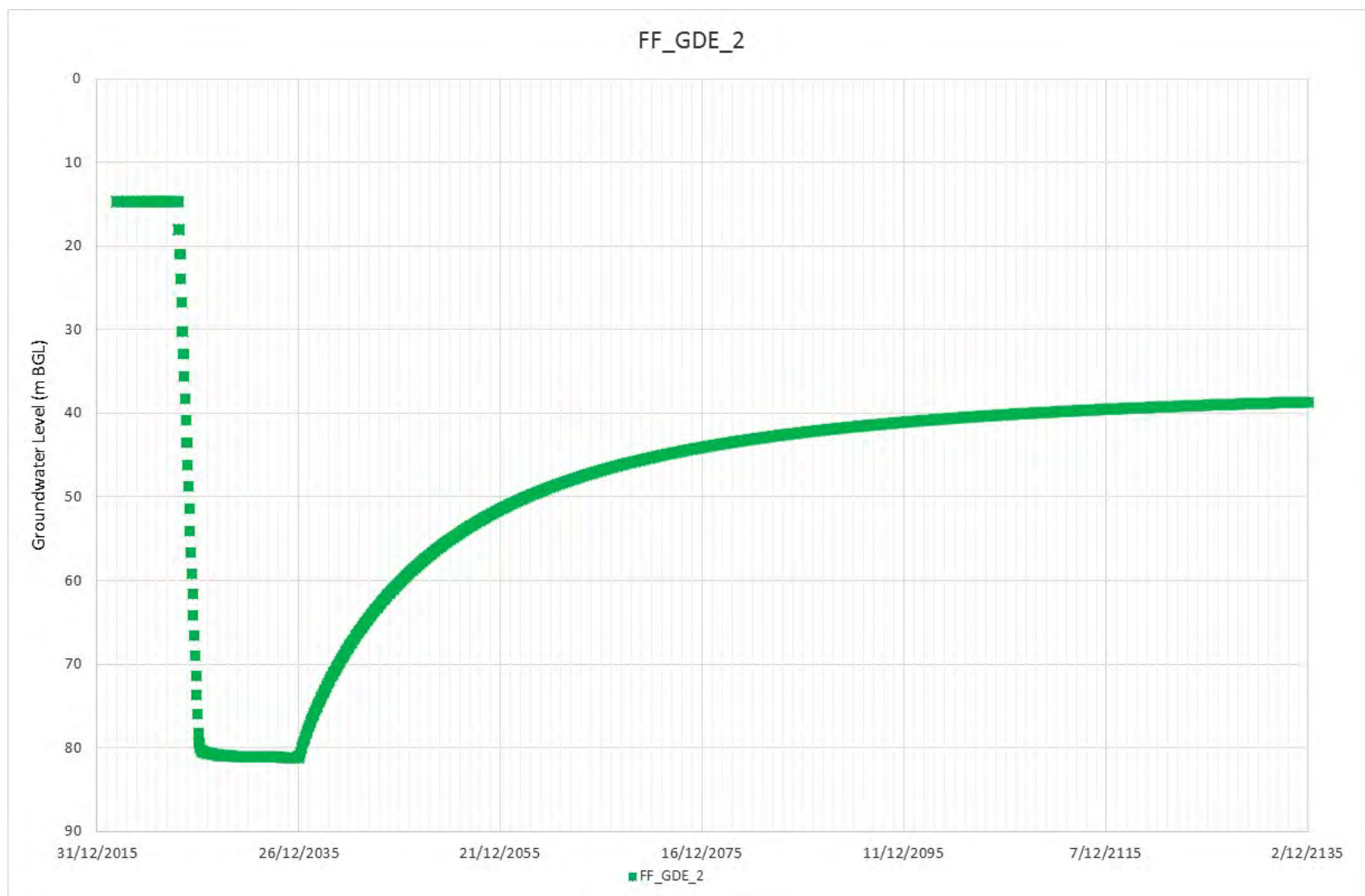
GDE Tracking Points





APPENDIX D

GDE Tracking Points





APPENDIX E

Important Information



IMPORTANT INFORMATION RELATING TO THIS REPORT

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

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